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INFLUENCE OF FERTILITY LEVELS ON THE VARIETAL RESPONSE OF SUGARCANE.....*C. Samuels, P. Landrau, Jr., and B. G. Capó* 129

COMPARATIVE PRODUCTIVITY OF MERKER GRASS AND OF A KUDZU-MERKER GRASS MIXTURE AS AFFECTED BY SEASON AND CUTTING HEIGHT.....*Ruben Caro Costas and José Vicente Chandler* 144

THE CAROTENE CONTENT OF GREEN AND RIPE PLANTAINS *Conrado F. Asenjo and Elba I. Porrata* 152

ESSENTIALS OF SUCCESSFUL POTATO CULTURE IN PUERTO RICO *Juan Pastor Rodríguez and Pablo Landrau, Jr.* 157

IDENTIFICATION OF THE ANTHOCYANIN PRESENT IN THE ACEROLA WHICH PRODUCES COLOR CHANGES IN THE JUICE ON PASTEURIZATION AND CANNING.....*Rafael Santini, Jr., and Alice Huyke* 171

SOME LIMITATIONS IN THE USE OF THE AIR PICNOMETER FOR SOIL-POROSITY, SOIL-MOISTURE, AND PARTICLE-DENSITY DETERMINATIONS...*José Vicente Chandler, Servando Silva, and Jacinto Figarella* 179

TERMITES OF THE WEST INDIES: THE BAHAMAS, AND BERMUDA *Thomas E. Snyder* 189

RESEARCH NOTES

The Insects of "Almendrón," *Prunus occidentalis* Sw.....*George N. Wolcott* 203

Resistance by Plant Tissue High in Silica to Injury by Cyanide and Marine Borers.....*George N. Wolcott* 204

Preliminary Note on the Socalled Recovery of the Cane Variety B. 34104 from the Sugarcane Virus in Puerto Rico.....*J. Adsuar* 206

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Influence of Fertility Levels on the Varietal Response of Sugarcane

G. Samuels, P. Landrau, Jr., and B. G. Capó[1]

INTRODUCTION

There are many as yet unanswered questions concerning the relationships existing between sugarcane varieties and fertilizer applications or soil fertility. These questions are propounded by geneticists, agronomists, and soil technologists. Important among them are the following:

1. *Are the results of sugarcane-variety field trials valid for different fertility levels when they are performed at but one fertility level?*

The performance of field trials in sugarcane-variety research is normally carried out by planting the varieties to be tested in a given pattern to insure randomization, fertilizing all varieties at the same level, and then comparing yields of cane tonnage, sugar tonnage, and sucrose content. This procedure has been open to criticism in that, since all varieties are tested at a given fertility level, differences in cane-variety performance caused by fertility-level differences do not become evident. In other words, a high-yielding cane variety may not hold the same rank at high- or low-nitrogen levels as in a variety trial under a medium-nitrogen level. The same might hold for phosphorus or potassium differences in fertility.

2. *Is it necessary to run fertilizer field trials on new varieties?*

The agronomist is concerned as to whether all sugarcane varieties exhibit a similar response to fertilizer applications. If so, then it is not necessary to perform new fertilizer trials every time a new variety appears for commercial use. If not, then it is incorrect to make a fertilizer recommendation for a cane variety on the basis of data from field tests with another variety.

3. *Should certain sugarcane varieties be recommended for soils of low fertility and different varieties for soils of medium or higher fertility?*

Very often different cane varieties have been recommended for soils of low and of high fertility. These recommendations have usually been based

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The authors wish to acknowledge the cooperation of those members of the Agronomy and Horticulture Department, past and present, who assisted in carrying out the fieldwork.

TABLE 1.—*General field data of the variety-fertilizer experiments with sugarcane evaluated herein, which were carried on in different areas of Puerto Rico*

Areas and experiment No.	Location	Soil type	Varieties	Fertilizer levels	Replications	Plot size	Crops
				Number	*Number*	*Acre*	*Number*
Humid							
1	Colonia San Francisco, Central Cambalache, Arecibo	Coloso silty clay	P.O.J. 2878, P.R. 903, M. 275, M. 317	7	9	1/72	5
2	Central Coloso, Aguadilla	Coloso clay	M. 28, M. 275, P.R. 902 P.R. 905	7	9	1/60	4
3	Field 7, Colonia Constancia, Toa Baja	Coloso silt loam	B.H. 10(12), P.O.J. 2878, M. 28, M. 275	7	6	1/30	2
Semihumid							
4	Isabela Substation, Isabela	Coto clay	M. 28, P.O.J. 2878, P.R. 902, P.R. 905	7	9	1/68	4
Arid-nonirrigated							
5	Lajas Substation, Lajas	Fraternidad clay	P.O.J. 2878, P.R. 905, P.R. 902, B. 34104	10	6	1/100	1
Arid-irrigated							
6	Sta. Ana Field, Colonia Josefa, Aguirre	Machete clay loam	P.O.J. 2961, B.H. 10(12) P.O.J. 2878, M. 341	10	6	1/60	1
7	Field 31, Central Aguirre, Aguirre	Aguirre clay	B.H. 10(12), P.O.J. 2878	12	8	1/75	1
8	Central Mercedita, Ponce	Mercedita clay	B.H. 10(12), P.O.J. 2878	12	8	1/75	1

on empirical characteristics and observations but rarely have data been available concerning the yield response of different varieties to different fertilizers applied at different levels.

OBJECTIVES

Accordingly, to determine whether differences in variety response can be expected when fertilizers or fertility levels are varied, data were analyzed from a series of variety-fertilizer sugarcane experiments conducted by the Agronomy and Horticulture Department of the Agricultural Experiment Station of the University of Puerto Rico. The purpose of this paper is to evaluate the interactions between cane varieties and fertility levels as used in these field experiments in order to determine whether significant and measurable differences exist, and whether valid answers can be found to the three basic questions mentioned above.

PROCEDURE

The experiments were conducted with 11 sugarcane varieties on 6 soil series. The complete list of varieties, soils, and locations is given in table 1. The fertility levels were controlled by differential fertilization as indicated in the fertilizer-treatment columns of tables 2 to 4, inclusive (see pp., 132, 135–7). The treatment where none of a particular fertilizer element was applied was considered the low instead of the no-fertility level for that element, as there was always some natural supply of the particular element already in the soil.

All experiments were harvested according to standard procedures of the Station, and yields were calculated and analyzed statistically according to the layout of the individual experiment.

RESULTS

The yields of the cane varieties at the different fertilizer levels are given in tables 2 to 4 (pp. 132, 135–7). The experiments chosen represent the humid, semihumid, arid-irrigated, and arid-nonirrigated areas. For the sake of brevity, it was assumed that the fertility status of a particular soil in those experiments was high in regard to the element concerned when additional application produced no significant yield increase. In these cases, the varying treatments were omitted from the tables except for the high-fertility level.

THE HUMID AREA

Results of the Colonia San Francisco, the Central Coloso, and the Colonia Constancia, experiments are shown in table 2.

Colonia San Francisco Experiment

NITROGEN.—At the low-nitrogen level, P.O.J. 2878 was significantly

TABLE 2.—*Comparison of the yield of sugarcane varieties at different fertilizer levels in the humid area*

Treatment No.	Fertility level	Fertilizer treatment per acre of—			Yield of available 96° sugar per acre for—			
		N	P_2O_5	K_2O	P.O.J. 2878	P.R. 903	M. 275	M. 317
	Colonia San Francisco experiment							
		Lb.	*Lb.*	*Lb.*	*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*
1	Low N	0	300	300	101	98	91	92
2	Medium N	125	300	300	134	146	128	136
3	Low K	250	300	0	126	143	127	135
4	Medium K	250	300	150	139	158	126	137
5	High N, P, K	250	300	300	141	160	138	145
	Least significant difference needed between fertilizer treatments for any one variety at:							
	5-percent level				7	7	7	7
	1-percent level				10	10	10	10
	Least significant difference needed between varieties for any one fertilizer treatment:							
	5-percent level				9	9	9	9
	1-percent level				12	12	12	12
	Central Coloso experiment							
					M. 28	M. 275	P.R. 902	P.R. 905
					Cwt.	*Cwt.*	*Cwt.*	*Cwt.*
1	Low N	0	300	300	79	86	97	87
2	Medium N	125	300	300	107	116	126	120
3	Low K	250	300	0	108	104	114	111
4	Medium K	250	300	150	115	121	122	125
5	High N, P, K	250	300	300	111	130	132	128
	Least significant difference needed between fertilizer treatments for any one variety at:							
	5-percent level				8	8	8	8
	1-percent level				10	10	10	10
	Least significant difference needed between varieties for any one fertilizer treatment:							
	5-percent level				9	9	9	9
	1-percent level				11	11	11	11
	Colonia Constancia experiment							
					B.H. 10(12)	P.O.J. 2878	M. 28	M. 275
					Cwt.	*Cwt.*	*Cwt.*	*Cwt.*
1	Low N	0	200	200	47	45	36	42
2	Medium N	83	200	200	55	58	50	50
3	Low K	165	200	0	54	56	53	55
4	Medium K	165	200	100	57	60	55	60
5	High N, P, K	165	200	200	59	63	54	65

TABLE 2.—*Continued*

Least significant difference needed between fertilizer treatments for any one variety at:				
5-percent level	5	5	5	5
1-percent level	7	7	7	7
Least significant difference needed between varieties for any one fertilizer treatment at:				
5-percent level	6	6	6	6

better than M. 275 and M. 317. For the medium- and high-nitrogen levels P.R. 903 yielded best, followed by M. 317, P.O.J. 2878, and M. 275, in order. In this experiment P.O.J. 2878 had good yielding power as compared with the other varieties at the low-nitrogen level, but at higher levels it was inferior to P.R. 903. All four varieties displayed a significant response to all nitrogen applications.

PHOSPHORUS.—No significant response was obtained to phosphate fertilizer, so this soil may be considered as having a high phosphorus fertility status for sugarcane. Under the high-phosphorus treatment 5, P.R. 903 yielded best of all, the other varieties giving significantly lower yields.

POTASSIUM.—P.R. 903 had the highest yields at the low-potassium level, followed by M. 317, and M. 275, P.O.J. 2878, in order. At the medium-potassium level, P.R. 903 was definitely superior, and P.O.J. 2878 and M. 317 had significantly higher yields than M. 275. At the high-potassium level P.R. 903 was first and the other three varieties were significantly lower in yield.

Applications of 150 pounds of K_2O per acre produced significant responses from P.O.J. 2878 and P.R. 903 whereas, 300 pounds of K_2O produced significant responses from M. 275 and M. 317.

Central Coloso Experiment

NITROGEN.—Variety P.R. 902 gave the highest yields for the low-nitrogen level, and yields of the other three varieties were all significantly lower. This did not hold true at the medium- and high-nitrogen levels, where P.R. 905 improved to the point where it and P.R. 902 were the highest yielders; M. 275 was next. M. 28 had significantly the lowest yields.

The use of 125 pounds of nitrogen per acre produced significant yield responses in all four varieties. However, only M. 275 and P.R. 905 responded significantly at the 250-pound level.

PHOSPHORUS.—No discernible response was obtained from phosphate fertilizer. In the fertility-level treatment 5, M. 28 was inferior to the other three varieties, all of which yielded about alike.

POTASSIUM.—At the low-potassium level, M. 275 was inferior to P.R. 902 with M. 28 and P.R. 905 showing intermediate ranking. At the medium-

potassium level, M. 28 produced significantly lower yields than P.R. 905, and at the high-potassium level was significantly lowest of all.

All varieties except M. 28 responded significantly with increased yields to the application of 150 pounds of K_2O per acre. But only M. 275 and P.R. 902 produced further significant increases when 300 pounds of K_2O per acre were applied.

Colonia Constancia Experiment

NITROGEN.—Varieties B.H. 10(12) and P.O.J. 2878 were superior in yields to M. 275 and M. 28 at the low- and medium-nitrogen levels. At the high-nitrogen level, M. 275 and P.O.J. 2878 were superior to M. 28, and B.H. 10(12) was intermediate in yield.

All varieties responded positively to applications of 83 pounds of nitrogen per acre. Only M. 275 produced a significantly increased yield when 165 pounds of nitrogen per acre were applied.

PHOSPHORUS.—There was no significant yield response to phosphorus. At the high-phosphorus level, treatment 5, M. 28, had a significantly lower yield than did P.O.J. 2878 and M. 275

POTASSIUM.—No appreciable differences in yield of varieties were evident at the low-potassium level. M. 28 yielded least at the medium- and high-potassium levels.

Only M. 275 gave a significant and positive response to potash at all potassium levels. P.O.J. 2878 did respond significantly to an application of 100 pounds of K_2O per acre.

THE SEMIARID AREA

Isabela Substation Experiment

Results of the Isabela Substation experiment are shown in table 3.

NITROGEN.—P.R. 902 was superior to the other varieties in yields at the low-nitrogen level; P.R. 905 stood next; M. 28 and P.O.J. 2878 were definitely inferior to them. At the medium- and high-nitrogen levels, P.R. 905 about equalled P.R. 902 in yield, and both were superior to M. 28 and P.O.J. 2878.

Except for P.R. 902, all the varieties significantly increased in yield when 125 pounds of nitrogen per acre were used.

None of the varieties responded significantly to the use of 250 pounds of nitrogen per acre.

PHOSPHORUS.—P.R. 902 gave the highest yields at the low-phosphorus level, followed by P.R. 905, M. 28, and P.O.J. 2878, in order. As was the case with nitrogen, P.R. 905 increased in yield at the medium- and high-phosphorus levels so much that there P.O.J. 2878 had the lowest yields.

All varieties except P.R. 902 produced significantly increased yields when 150 pounds of P_2O_5 were used per acre, but none did so when 300 pounds P_2O_5 were applied.

POTASSIUM.—Potash had no significant influence on yields. It was assumed, therefore, that the potassium fertility of this soil was high. At the high-potassium level, treatment 5, P.R. 902 and P.R. 905, was superior to M. 28 and P.O.J. 2878 in yields.

TABLE 3.—*Comparison of the yields of sugarcane varieties at different fertilizer levels in the semihumid area, Isabela Substation experiment*

Treatment	Fertility level	Fertilizer treatment per acre of—			Yield of available 96° sugar per acre for—			
		N	P_2O_5	K_2O	M. 28	P.O.J. 2878	P.R. 902	P.R. 905
		Lb.	*Lb.*	*Lb.*	*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*
1	Low N	0	300	300	59	51	96	80
2	Medium N	125	300	300	74	68	103	105
3	Low P	250	0	300	65	59	102	89
4	Medium P	250	150	300	78	71	111	101
5	High N, P, K	250	300	300	80	73	108	108
Least significant difference needed between fertilizer treatments for any one variety at:								
	5-percent level				10	10	10	10
	1-percent level				13	13	13	13
Least significant difference needed between varieties for any one fertilizer treatment at:								
	5-percent level				11	11	11	11
	1-percent level				14	14	14	14

ARID-NONIRRIGATED AREA

Lajas Experiment

The results of the Lajas Substation, arid-nonirrigated; Colonia Josefa, arid-irrigated; and the Central Aguirre, arid-irrigated experiments are shown in table 4.

NITROGEN AND PHOSPHORUS.—There was no significant responses in yield to the use of either nitrogenous or phosphatic fertilizers, and the soil-fertility status for these elements was regarded as high. B. 34104 was the leading variety with the other three decidedly inferior in yield.

POTASSIUM.—At all potassium levels B. 34104 was superior in yield to the other varieties. Some imporvement was shown by P.O.J. 2878 at the medium- and high-potassium levels, but only P.O.J. 2878 responded significantly in yield when 200 pounds of K_2O were applied.

TABLE 4.—*Comparison of the yields of sugarcane varieties at different fertilizer levels in the arid-nonirrigated and the arid-irrigated areas*

Treatment No.	Fertility level	Fertilizer treatment per acre of—			Yield of available 96° sugar per acre for—			
		N	P_2O_5	K_2O	P.O.J. 2878	P.R. 905	P.R. 902	B. 34104
	Lajas Substation, arid-nonirrigated							
		Lb.	*Lb.*	*Lb.*	*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*
1	Low K	200	240	0	78	72	86	128
2	Medium K	200	240	120	105	84	80	143
3	High N, P, K	200	240	240	108	88	98	169
	Least significant difference needed between fertilizer treatments for any one variety at:							
	5-percent level				22	22	22	22
	1-percent level				29	29	29	29
	Least significant difference needed between varieties for any one fertilizer treatment at:							
	5-percent level				28	28	28	28
	Colonia Josefa experiment, arid-irrigated area							
					P.O.J. 2961	B.H. 10(12)	P.O.J. 2878	M. 341
		Lb.	*Lb.*	*Lb.*	*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*
1	Low N	0	360	360	131	119	109	93
2	Medium N	100	360	360	153	151	142	124
3	High N	200	360	360	146	160	149	133
4	Very high N, P, K	300	360	360	154	149	132	137
	Least significant difference needed between fertilizer treatments for any one variety at:							
	5-percent level				22	22	22	22
	1-percent level				29	29	29	29
	Least significant difference needed between varieties for any one fertilizer treatment at:							
	5-percent level				23	23	23	23
	Central Aguirre experiment, arid-irrigated area							
					Yield of cane per acre for—			
					B.H. 10(12)		P.O.J. 2878	
		Lb.	*Lb.*	*Lb.*	*Tons*		*Tons*	
1	Medium N	125	300	400	36		37	
2	High N	250	300	400	37		40	
3	Very high N, P, K	375	300	400	42		45	
4	Very high N	500	300	400	46		51	
	Least significant difference needed between treatments at:							
	5-percent level				5		5	
	1-percent level				7		7	

TABLE 4.—*Continued*

Central Mercedita experiment, arid-irrigated area

Treatment No.	Fertility level	Fertilizer treatment in pounds per acre of—			Yield of cane per acre for—	
		N	P_2O_5	K_2O	B.H. 10(12)	P.O.J. 2878
		Lb.	*Lb.*	*Lb.*	*Tons*	*Tons*
1	Low N	125	300	300	91	108
2	High N	250	300	300	91	111
3	Very high N, P, K	375	300	300	95	102
4	Very high N	500	300	300	100	109
Least significant difference needed between treatments at:						
	5-percent level				5	5
	1-percent level				7	7

ARID-IRRIGATED AREA

Colonia Josefa Experiment

NITROGEN.—At the low- and medium-nitrogen levels P.O.J. 2961 and B.H. 10(12) yielded better than M. 341, with P.O.J. 2878 intermediate between them. B.H. 10(12) had the highest yields at high-nitrogen levels and M. 341 had significantly lower yields than the other varieties. At the very high-nitrogen levels, yields of B.H. 10(12) and P.O.J. 2878 decreased, but P.O.J. 2961 yielded significantly more than P.O.J. 2878.

Applications of 100 pounds of nitrogen per acre produced significant yield increases in all varieties, but this was not true when 200 or 300 pounds of nitrogen per acre were used, as compared with yields at 100 pounds.

PHOSPHORUS AND POTASSIUM.—No significant responses in yields were obtained for either phosphate or potash fertilizers. The fertility status of the Machete clay loam in respect to these two elements may be assumed high.

Central Aguirre Experiment

NITROGEN.—P.O.J. 2878 outyielded B.H. 10(12) in cane per acre at all nitrogen levels. The differences in yields grew greater with increasing nitrogen applications. Significant yield increases were obtained when 375 pounds of nitrogen per acre were used, as compared with 250 pounds.

PHOSPHORUS AND POTASSIUM.—Phosphate and potash applications produced no significant increases in yield. These soils may be presumed high in phosphorus and potassium. P.O.J. 2878 had higher yields than B.H. 10(12).

Central Mercedita Experiment.

No significant yield differences were obtained at any fertility level for nitrogen, phosphorus, or potassium for the two varieties used, P.O.J. 2878 and B.H. 10(12). The average for all fertility levels was 108 tons of cane per acre for P.O.J. 2878, as compared with 98 tons for B.H. 10(12). P.O.J. 2878 outyielded B.H. 10(12) at all fertility levels.

DISCUSSION

It would be well now to review the three questions asked in the Introduction in light of our experimental results.

1. *Are the results of sugarcane-variety field trials valid for different fertility levels when they are performed at one fertility level?*

The experimental data indicate that many varieties do not tend to keep their relative rank at various fertility levels. A summary of the ranking of the varieties in respect to cane-yield responses for the various experiments is given in table 5. The results show that certain varieties which ranked low at a given fertility level, as compared with other varieties, yielded as well as the high-ranking varieties when grown at another fertility level. For example, if a plant breeder were conducting a sugarcane-variety trial at low-nitrogen levels as in the Central Coloso experiment, he would find that P.R. 902 alone was the statistically outstanding variety in yields (see tables 2 and 5). However, at medium-nitrogen levels he would find that P.R. 905 and P.R. 902 were the best. At high-nitrogen levels his data would show that there were no significant yield differences between P.R. 902, P.R. 905, and M. 275, and all three would outyield M. 28 significantly.

This change in rank at various fertility levels occurred also for nitrogen and potassium in the Colonia San Francisco experiment, phosphorus in the Central Coloso experiment, nitrogen and potassium in the Colonia Constancia experiment, nitrogen and phosphorus in the Isabela Substation experiment, and nitrogen in the Colonia Josefa experiment. Van Dillewijn (2)[2] also reported evidence from both Java and Hawaii that certain cane varieties revealed a differential response to fertilizers at various fertility levels.

From the data presented it appears that, when variety trials are made at one fertility level, this alone may obscure the selection of certain promising varieties which might perform as well as, or better than, those chosen at another fertility level. This change in ranking with change in fertility level may help explain why a variety which has shown high rank in a variety trial sometimes fails to give good results when recommended for commercial use where conditions of soil fertility are not the same as those under which the trial was conducted.

[2] Numbers in parentheses refer to Literature Cited, p. 143.

TABLE 5.—*The ranking of certain sugarcane varieties with respect to cane-yield responses at different fertility levels*[1]

Experiment and variety	Cane-varietal rank at indicated fertility levels								
	Nitrogen			Phosphorus			Potassium		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Colonia San Francisco experiment									
P.R. 903	1	1	1	—	—	1	1	1	1
P.O.J. 2878	1	2	2	—	—	2	2	2	2
M. 317	2	2	2	—	—	2	1	2	2
M. 275	2	2	2	—	—	2	2	2	2
Central Coloso experiment									
P.R. 902	1	1	1	—	—	1	1	1	1
P.R. 905	2	1	1	—	—	1	1	1	1
M. 28	2	3	2	—	—	2	1	2	2
M. 275	2	2	1	—	—	1	2	1	1
Colonia Constancia experiment									
B.H. 10(12)	1	1	1	—	—	1	1	1	1
P.O.J. 2878	1	1	1	—	—	1	1	1	1
M. 28	2	2	2	—	—	2	1	2	2
M. 275	1	2	1	—	—	1	1	1	1
Isabela Substation experiment									
P.R. 902	1	1	1	1	1	1	—	—	1
P.R. 905	2	1	1	2	1	1	—	—	1
M. 28	3	2	2	3	2	2	—	—	2
P.O.J. 2878	3	2	2	3	2	2	—	—	2
Lajas Substation experiment									
B. 34104	—	—	1	—	—	1	1	1	1
P.O.J. 2878	—	—	2	—	—	2	2	2	2
P.R. 902	—	—	2	—	—	2	2	2	2
P.R. 905	—	—	2	—	—	2	2	2	2
Colonia Josefa experiment									
P.O.J. 2878	1	1	1	—	—	1	—	—	1
P.O.J. 2961	1	1	1	—	—	1	—	—	1
B.H. 10(12)	2	2	2	—	—	2	—	—	2
M. 341	2	1	1	—	—	1	—	—	1

[1] All differences between any ranking are statistically significant at the 5-percent level.

2. *Is it necessary to run fertilizer field trials on new varieties?*

In view of the experimental data obtained it appears that the use of one variety only to determine soil fertility, fertilizer responses, or cane fertilizer requirements may be misleading. For instance, results obtained in the humid area (table 2) on the nitrogen requirements of cane revealed that all varieties responded significantly to the first nitrogen increment

from low-nitrogen to medium-nitrogen fertility levels. However, when the second nitrogen increment is considered, from medium-nitrogen to high-nitrogen levels, there were differences in the responses attributable to varieties. In the Coloso experiment M. 275 showed a significant response in yield whereas the others did not (table 2, treatment 2 versus treatment 5). In the Constancia experiment M. 275 also responded to a second increment of nitrogen, whereas B.H. 10(12) and M. 28 failed to do so.

Similar difference in variety response to a given fertilizer application was noted for the other areas, and for all three elements, nitrogen, phosphorus, and potassium. Therefore, fertilizer recommendations based on experiments with one variety may not necessarily be valid for new varieties. To obtain more precise information on the fertilizer requirements of sugarcane it may be necessary to perform fertilizer field trials for the leading varieties, rather than to base recommendations on the performance of any one variety in a fertilizer test.

3. *Should certain sugarcane varieties be recommended for soils of low fertility and different varieties for soils of medium or higher fertility?*

The data obtained indicate that some varieties do not tend to maintain their yielding rank at various fertility levels. The recommendation of a variety which has ranked high at medium- or high-fertility levels may not necessarily be the wisest choice for a soil of a low fertility level. For example, at the Isabela Substation, P.R. 905 gave an outstanding performance at medium- and high-nitrogen levels, but was only second to P.R. 902 at low-nitrogen levels (see table 5). For soils of medium- or high-nitrogen fertility in that area P.R. 902 or P.R. 905 would both be suitable. Only P.R. 902 should be recommended where low-nitrogen levels are encountered. Therefore, it appears that certain varieties do perform comparatively better than others at different fertility levels.

CONCLUSIONS

In general, there is some interaction between sugarcane varieties and fertilizers. A summary of the interactions and their significance for the eight experiments is given in table 6. In three of the eight experiments there were statistically significant interactions between variety and fertilizer.

Low or no interaction between fertilizer and variety has been found for such crops as sugar beets (5), potatoes (3), and peanuts (6), whereas, significant interactions were noted between variety and fertility levels for corn and wheat. Frey (4) has suggested that, in general, crops in which one variety has a small area of adaptation, corn, for example, tend to show a significant variety-by-fertility-level interaction, while crops in which any

one variety has a large area of production, such as oats, do not show such significant interactions.

Sugarcane varieties are normally grown over wide areas; however, certain varieties developed in one geographic area appear to do better in there than elsewhere. Davidson (1), using selected varieties of the sugarcane areas in Louisiana, mainly Canal Point varieties, did find significant variety-by-fertility interactions.

The sugarcane varieties commercially used in Puerto Rico are of both types. In 1949 over 65 percent of the cane planted was P.O.J. 2878, with B.H. 10(12) accounting for 15 percent (7). The P.O.J. 2878 variety is grown

TABLE 6.—*The F value and significance for varieties, fertilizers, and variety-fertilizer interactions for the cane experiment evaluated herein*[1]

Experiment	Crops	Variety F value	Fertilizer F value	Variety fertilizer interaction F value
	Number			
1. Colonia Constancia	1	5.01*	82.67**	2.21**
2. Colonia San Francisco	5	17.23**	180.68**	3.19**
3. Central Coloso	4	13.03**	94.16**	1.95
4. Isabela Substation	4	86.53**	84.90**	.91
5. Lajas Substation	1	11.09**	2.79**	1.34
6. Colonia Josefa	1	26.24**	8.09**	.72
7. Central Aguirre	1	14.71**	5.45**	.90
8. Central Mercedita	1	59.30**	.75	2.01**

[1] * Significant difference at the 5-percent level, ** significant difference at the 1-percent level.

over wide areas and is not restricted in its response to any one. However, B.H. 10(12) has shown a better response in the irrigated southern coast than in the humid northern coast.

Soil fertility is a product not only of the nutrient elements present in it, but also of such factors as rainfall, drainage, depth of soil profile, temperature, and soil texture, Therefore, differences in soil fertility do exist for different sugarcane areas. These differences do not evoke the same response for all sugarcane varieties. Whereas some varieties may acclimate themselves and perform well at many fertility levels under a wide range of climatic conditions, other varieties tend to be more selective in their soil-fertility and climatic needs and to perform much better in some places than in others. Thus it appears important that adequate consideration be given to the influence of fertility on varietal response in sugarcane when testing new sugarcane varieties.

SUMMARY

There are many as yet unanswered questions concerning the relationship between sugarcane varieties and soil fertility. Important among them are the following:

1. Are the results of sugarcane-variety field trials valid for different fertility levels when performed at but one fertility level?

2. Is it necessary to run fertilizer field trials on new varieties?

3. Should certain sugarcane varieties be recommended for soils of low fertility and different varieties for soils of medium or higher fertility?

Statistical examination of the data from eight variety-fertilizer experiments carried on in different parts of Puerto Rico: Humid, semihumid, arid-irrigated, and arid-nonirrigated, and also on different soil types, revealed the following answers to these questions concerning differences in varietal response to different fertility or fertilizer levels, using nitrogen, phosphorus, and potassium:

1. Certain varieties did not consistently yield best at all fertility levels.

2. Some varieties appeared to do better at higher fertility levels than at low ones; others performed better at low fertility levels.

3. Inasmuch as varietal response is different at various fertility levels, caution is recommended in evaluating new variety trials at only one fertility level.

4. Not all varieties responded similarly to fertilizer applications, and it would be misleading to define fertilizer requirements or the fertility level on the basis of the performance of one cane variety only, if other varieties are to be grown in that area.

5. A discussion of the interaction of varieties and fertilizers is presented in which it is suggested that some cane varieties developed in one geographic area do better there than elsewhere, while other varieties grow well over wide areas.

RESUMEN

El examen estadístico de los datos obtenidos de ocho experimentos en los cuales se usaron distintas variedades de caña de azúcar y distintos tratamientos de abonos, y llevados a cabo en zonas húmedas, semi-húmedas, áridas con y sin riego, de Puerto Rico, así como también en varios tipos de suelos, reveló que las variaciones observadas en la producción de las variedades, respecto al uso variable de nitrógeno, fósforo y potasio, pueden resumirse de la manera siguiente:

1. Algunas variedades no produjeron consistentemente bien en todos los niveles de fertilidad estudiados.

2. Algunas variedades respondieron mejor a niveles altos de fertilidad

que a niveles bajos; mientras que otras, su comportamiento fué todo lo contrario.

3. Tomando en consideración la reacción versátil de las variedades a los distintos niveles de fertilidad, se discute en el presente trabajo las precauciones que deben tomarse al llevar a cabo futuros experimentos con abonos.

4. Todas las variedades no reaccionan igualmente al uso de abonos y por lo tanto sería incorrecto el determinar los requisitos de los mismos a base del comportamiento de una sola variedad.

5. Se presenta una exposición de la acción recíproca ocurrida entre las variedades y los fertilizantes lo cual lleva a suponer que algunas variedades se comportan mejor que otras en cierta y determinada región, mientras que otras se desarrollan espléndidamente en distintas regiones.

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Comparative Productivity of Merker Grass and of a Kudzu-Merker Grass Mixture as Affected by Season and Cutting Height

Ruben Caro-Costas and José Vicente-Chandler[1]

INTRODUCTION

Elephant grass (*Pennisetum purpureum*) of which Merker is a variety, is widely recognized as the outstanding soilage grass of the humid Tropics. Tropical kudzu (*Pueraria phaseoloides*) is the only forage legume of economic importance in Puerto Rico and its use is spreading rapidly throughout tropical America, largely as a result of the research conducted in Puerto Rico (1).[2] When grown together these forages have outyielded all other grass-legume mixtures tested in an experiment being conducted by R. Freyre and coworkers (2). During the first year of a grazing experiment being conducted by Caro and Vicente (3), pastures seeded to these forages carried over two head per acre and produced approximately 1,100 pounds of beef per acre yearly on steep slopes in the humid mountain region of Puerto Rico. This is by far the highest beef yield ever obtained from pastures under similar conditions in Puerto Rico. However, since these pastures are difficult to manage, their use cannot be recommended until further research is performed.

Vicente, Silva, and Figarella (3) have shown that Merker grass growing alone in the humid region of the Island responds almost linearly in yield to nitrogen applications of up to 800 pounds of this nutrient per acre yearly. At this level Merker grass produced 130 tons of green forage (23 tons of dry matter) annually per acre during the first year, or enough to feed six mature animals per acre if the forage were fully utilized.

There are no data available comparing the productivity of Merker grass well fertilized with nitrogen with that of a kudzu-Merker grass association, or on the growth of these forages during different seasons of the year in the mountain region of Puerto Rico. Neither is information available on the effect of heights of cutting on yields of Merker grass. Vicente and Caro (4) however, have shown that yields of tropical kudzu are reduced by repeated close cutting.

[1] Agronomist and Project Supervisor, respectively, of a cooperative research project between the Agricultural Research Service of the U. S. Department of Agriculture and the Agricultural Experiment Station of the University of Puerto Rico, Río Piedras, P. R.

[2] Numbers in parentheses refer to Literature Cited in pp. 150–1.

OBJECTIVE

The purpose of the present study was to determine the relative yields of Merker grass well fertilized with nitrogen, and of a kudzu-Merker grass association, as affected by cutting height and season of the year, when harvested for use as soilage.

MATERIALS AND METHODS

This experiment was carried out over a period of 2 years at Orocovis, P. R., which lies at an elevation of about 2,000 feet above sea level. Conditions here are typical of the mountain region of the Island where lies the greatest potential for livestock production. The annual rainfall is about 70 inches, the mean annual temperature is about 80°F., and the mean seasonal variation in temperature is about 10°F.

The soil is a deep-red, kaolinitic Catalina clay with a slope of about 25 percent. The surface soil has a pH of about 5.1, a total exchange capacity of 17.2 m.eq. per 100 gm. of soil, a total exchangeable base content of 6.4 m.eq. per 100 gm. of soil, an organic-matter content of 4.1 percent, a bulk density of 1.18, and an available water-holding capacity of about 8.4 percent.

The land was plowed several times and Merker grass was planted in rows 4 feet apart with kudzu seeded between rows where required. The entire area was carefully managed until a uniform stand and a desirable species balance was attained.

The soil was limed to approximately pH 6.5. Two hundred pounds of phosphorus and 200 pounds of potassium were applied per acre yearly to all plots in the form of 20-percent superphosphate and potassium sulfate, respectively. Fifty pounds of nitrogen, in the form of ammonium sulfate, were applied to the Merker grass plots after each cutting. Since the forage was cut six times yearly, a total of 300 pounds of nitrogen were applied per acre yearly.

A split-plot design was used with Merker grass and the kudzu-Merker grass mixture as the main plots and the height-of-cutting variables—2 and 10 inches above ground level—as the subplots. Individual plots were 8 by 16 feet in size. All treatments were replicated six times.

The herbage in all plots was harvested about every 2 months, and all the forage was removed from the experimental area. No special effort was made to harvest the kudzu growing between the rows of Merker grass so that generally only that climbing the grass stalks was cut.

The dry weight of forage produced by each plot was determined, as was the proportion of kudzu and Merker grass. The crude-protein content of all samples was determined by standard methods.

A record of rainfall was kept during the entire course of the experiment.

RESULTS AND DISCUSSION

MERKER GRASS VS. A KUDZU-MERKER GRASS ASSOCIATION

The data in table 1 show that Merker grass growing alone and receiving nitrogen fertilization produced an average of 23,652 pounds of dry matter per acre yearly, or almost twice as much forage as did the kudzu-Merker grass association which yielded an average of only 12,232 pounds of dry

TABLE 1.—*The yield and protein content of Merker grass and of a kudzu-Merker grass mixture cut at two heights over a 2-year period on a Catalina clay soil at Orocovis*[1]

Forages and treatments	Dry-matter yield per acre per year	Protein	Protein yield per acre per year	Dry-matter yield per acre per year	Protein	Protein yield per acre per year	Dry-matter yield per acre per year	Protein	Protein yield per acre per year
	Pounds	*Percent*	*Pounds*	*Pounds*	*Percent*	*Lb.*	*Pounds*	*Percent*	*Pounds*
Merker grass[2]									
Cut at 2″ height...	25,170	7.3	1,842	—	—	—	—	—	—
Cut at 10″ height...	22,135	7.7	1,705	—	—	—	—	—	—
Average.....	23,652	7.5	1,773	—	—	—	—	—	—
Forages and treatments	*Total yields*			*Yields of Kudzu*			*Yields of Merker*		
Kudzu-Merker grass[3]									
Cut at 2″ height...	12,902	7.3	941	2,009	16.7	336	10,893	5.6	605
Cut at 10″ height...	11,562	8.6	989	2,521	17.0	428	9,041	6.2	561
Average.....	12,232	7.9	965	2,265	16.9	382	9,967	5.8	583

[1] All values are averages of 6 replications.

[2] Fertilized with 300 lb. of N per acre yearly applied in equal amounts after each harvest. Abundant Ca, K, and P were applied to all plots.

[3] All plots were fertilized with P, K, and lime.

matter per acre yearly. From the results cited previously it is likely that, had the Merker grass growing alone been more heavily fertilized with nitrogen, the differences in yield would have been even greater.

Since there was no significant difference in the protein content of the total forage produced in either case, the grass growing alone yielded almost twice as much protein per acre as did the grass-legume mixture. Merker grass itself, when grown alone, had a significantly higher protein content (7.5 percent as compared to 5.8 percent) than did that growing in association with tropical kudzu.

Although tropical kudzu contributed on the average only about 19 per-

cent of the dry matter produced by the mixture, it provided almost 40 percent of the protein because of the high protein content of this legume.

It is evident from the above that properly fertilized Merker grass cut for soilage can produce much more forage of as high a protein content as that of a kudzu-Merker grass association. This is an important consideration in such a heavily populated country as Puerto Rico, where maximum use must be made of the land. Furthermore, it is much easier to establish and to manage Merker grass growing alone.

Under grazing, however, the situation is different. Instead of removing from the field all the nitrogen contained in the forage, much of it is returned to the soil in the wasted or trampled herbage and in the excreta of the grazing animals, and is eventually available for use by the grass. Thus, under grazing, the difference in yield between Merker grass fertilized with nitrogen and a kudzu-Merker grass association would be expected to be considerably less. Research is now under way to evaluate Merker grass pastures heavily fertilized with nitrogen under grazing management.

THE EFFECT OF CUTTING HEIGHT

The data in table 1 show that Merker grass, both alone and in association with tropical kudzu, produced significantly higher yields when cut 2 inches from the ground than when cut at a 10-inch height. Tropical kudzu, on the other hand, produced significantly more forage when cut at a 10-inch height. Because of this opposite, and therefore compensating influence, height of cutting had no apparent effect on yields of the kudzu-Merker grass association.

The protein content of the forage produced by the mixture, however, was significantly higher with high cutting (8.6 percent as compared to 7.3 percent with low cutting) due to the higher proportion of kudzu present. Height of cutting had no apparent effect on the protein content of either the Merker grass or the tropical kudzu.

It thus seems best to cut Merker grass growing alone at a height of about 2 inches above the ground, whereas a kudzu-Merker grass mixture should be cut considerably higher.

SEASONAL DISTRIBUTION OF FORAGE PRODUCTION

Figure 1 shows the seasonal distribution of forage produced by Merker grass and a tropical kudzu-Merker grass association. In both cases forage production was very unevenly distributed throughout the year. The difference was more marked in the case of Merker grass growing alone, however. Both the grass and the grass-legume mixture produced about twice as much forage during the so called "summer" months (April to October) as during the "winter" months.

Daily per acre production of dry matter by Merker grass growing alone varied from a minimum of about 20 pounds, or enough to provide the forage requirements of one mature animal, to a maximum of about 120 pounds. In general, this grass produced enough forage to supply the needs of two animals per acre during the winter months and four during the summer. The kudzu-Merker grass association produced a minimum of 10 pounds of dry matter per acre daily and a maximum of about 45 pounds. In general, this mixture produced sufficient forage to feed an animal per acre during the winter and two animals during the summer.

The question naturally arises as to what factor or combination of factors

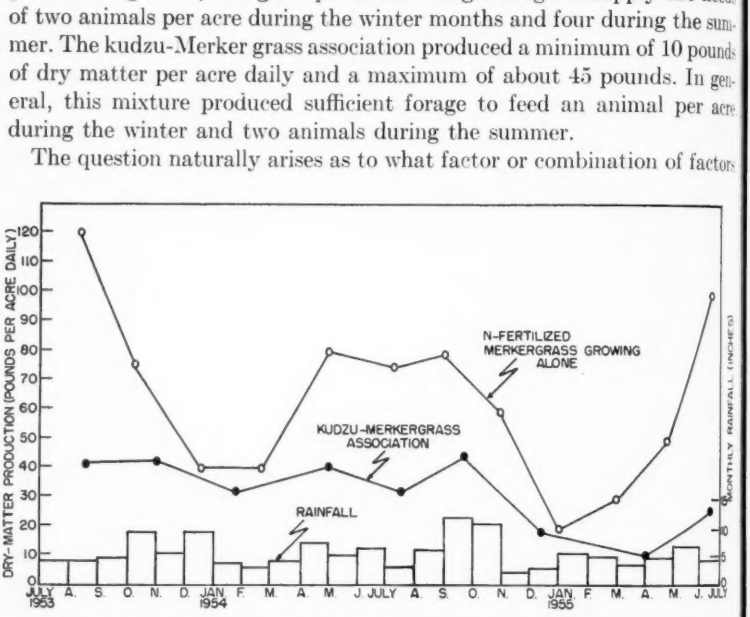

FIG. 1—The effect of season and rainfall on the productivity of Merker grass and of a Merker grass-kudzu association grown at Orocovis, P. R.

is responsible for the relatively low forage production during the winter months. The data shown in figure 1 indicate that rainfall was somewhat lower during the winter months. On the average, rainfall during the summer was about 6 inches monthly as compared to about 4.6 inches monthly during the winter.

A study of figure 1 shows that other factors apparently had a greater effect on forage production than did rainfall. Several examples can be used to illustrate this point. During the first year's peak period of growth, July–August, monthly rainfall averaged 4.5 inches as compared to 5.4 inches during the following minimum growth period of November–March 1954, when Merker grass produced only about a third as much forage. Similarly, rainfall alone could hardly have been responsible for the difference in forage production between the low of December–April 1955 (4.4

inches of rainfall monthly) and the periods of fast growth July–August 1953 (4.5 inches of rainfall monthly) and May–June 1955 (5.4 inches of rainfall monthly).

During the winter months the weather was somewhat cooler and the days considerably shorter than during the summer. Kudzu produces seed during the winter and Merker grass tends to flower at this time before attaining maximum development. It appears likely that the cooler weather and shorter days reduced vegetative growth and stimulated reproduction. These two factors seemed to exert a greater effect on yields than did rainfall. It is of interest to note that Vicente and Caro (3) found that Guinea grass produced much more forage during the summer than during the winter even though moisture was abundant.

The above raises a serious question as to the advisability of establishing supplemental irrigation systems for forages in the humid areas of Puerto Rico. This is sometimes done in an effort to equalize forage production throughout the year. An exception may be the sandy soils of the North Coast where moisture is limiting at different times of the year.

A more logical approach to the serious problem of uneven forage production throughout the year would probably be the use of silos to store the excess forage produced during the summer, the storage of herbage in the field through proper pasture management, and the use of forage crops which may grow more evenly throughout the year.

SUMMARY

The yields of a tropical kudzu-Merker grass association were compared to those of Merker grass growing alone and fertilized with 300 pounds of nitrogen per acre yearly. The effect of two heights of cutting and of season of the year on the productivity of these forages was also studied.

Merker grass produced 23,652 pounds of dry matter and 1,773 pounds of crude protein per acre yearly, or about twice as much dry matter and protein as did the kudzu-Merker grass association. Kudzu contributed about 19 percent of the dry matter and almost 40 percent of the protein produced by the association.

The Merker grass growing alone had a higher protein content than that growing with kudzu. Merker grass both alone and in association with kudzu yielded more when cut at a height of 2 inches from the ground than when cut at a 10-inch height. The reverse was true with tropical kudzu. Because of this compensating effect cutting height had no significant effect on yields of the kudzu-Merker grass mixture. Because of a higher proportion of kudzu, the protein content of the mixture was greater with high cutting, however.

Both Merker grass and the kudzu-Merker grass association yielded about

twice as much forage during the "summer" months as during the "winter" months. Lower rainfall, cooler temperature, and shorter days during the "winter" months appeared to be responsible for the reduction in growth occurring during this season. The latter two factors were apparently responsible for most of the difference in growth rates which suggest that only limited benefits may accrue from supplemental irrigation of forages during the "winter" months in the humid areas of Puerto Rico.

RESUMEN

Los rendimientos de una mezcla de kudzú tropical y yerba Merker fueron comparados con los de la yerba creciendo sola y abonada a razón de 300 libras de nitrógeno por cuerda por año. También se estudió el efecto de la estación del año y de dos alturas de corte en los rendimientos de estas forrajeras.

La yerba Merker produjo 23,652 libras de materia seca y 1,773 libras de proteina por cuerda por año. Esta cantidad resultó ser aproximadamente el doble de la producida por la mezcla de la yerba y la leguminosa. El kudzú tropical aportó alrededor del 19 por ciento de la materia seca y 40 por ciento de la proteina producidas por la mezcla.

La yerba Merker sola tuvo un contenido de proteina mayor que el de la yerba que creció en asociación con la leguminosa. La yerba sola o en asociación con la leguminosa produjo los más altos rendimientos cuando se cortó a 2 pulgadas del suelo. Por el contrario, el kudzú produjo rendimientos más altos cuando se cortó a 10 pulgadas de la superficie del suelo. Debido a este efecto compensativo no hubo diferencias significativas entre los rendimientos de la mezcla cortada a dos alturas. Sin embargo, el contenido de proteina en la mezcla cortada a 10 pulgadas resultó ser más alta que cuando se cortó a 2 pulgadas, debido a la mayor proporción de kudzú bajo este sistema de corte.

Tanto la yerba como la mezcla produjeron rendimientos mucho más altos durante los meses de verano que durante el invierno. Tal parece que la temperatura baja, los días cortos y la escasez de precipitación pluvial fueron los factores responsables de esta disminución en rendimientos.

Aparentemente los días cortos junto a temperaturas bajas fueron los factores predominantes en esta reducción, lo que hace pensar que el regadío suplementario no tendría gran efecto en el rendimiento de estos forrajes durante los meses de invierno en la región húmeda de Puerto Rico.

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The Carotene Content of Green and Ripe Plantains[1]

Conrado F. Asenjo and Elba I. Porrata[2]

INTRODUCTION

Plantain (*Musa paradisiaca* L.), either in the green or ripe stage, is extensively used in the Puerto Rican dietary although it must be cooked to be edible. In the survey of approximately 1,000 Puerto Rican families conducted by Robert and Steffani (1),[3] they found that 61.5 percent often used green, and 48.6 percent often used ripe plantains. It is also interesting to point out that the green plantain headed the list among the starchy vegetables in the order of preference, while the ripe plantain occupied the fourth place.

LITERATURE REVIEW

The information found in the literature on the carotene and vitamin A content of green and yellow plantains is very fragmentary. The only specific investigation on the subject found by us was that by Gómez and Mattill (2). They studied the carotene content of plantains during the progress of color change from stage 1 to stage 8. They found that, irrespective of the color stage, the carotene content fluctuated within the narrow limits of 2.4 to 3.9 μg. per gram of raw edible material. They did not determine carotene by the chromatographic method, but by a special extraction procedure.

All the other data on the carotene or vitamin A content of plantain have been of a fragmentary nature. Quinn and Cook (3) reported that plantains (state of maturity not indicated) purchased in Spanish stores in New York City contained 10 Sherman units of vitamin A per gram of the edible portion. Axtmayer and Cook (4) found that green Puerto Rican plantains, after being boiled in water, contained 20 Sherman units of vitamin A per gram of the edible portion. Munsell, *et al.* (5) (6) (7) (8) (9) (10), reported the results of analysis in 21 samples from Central America. The average carotene content was 3.6 μg. per gram. Their values ranged from 0.1 to 8.3 μg. per gram. Only one sample was green and it was 2.1 μg. lower than the average. Five samples of plantains from Mexico, of no stated stage of maturity, were reported by Cravioto, *et al.* (11), to contain between 2.5 and 9.0, and to average 5.0 μg. of carotene per gram of the edible portion.

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[3] Numbers in parentheses refer to Literature Cited pp. 155–6.

Navia, *et al.* (12), in 6 samples of plantains from Cuba, reported values ranging from 0.6 to 20.0, and averaging 6.6 μg. per gram of the edible portion. They pointed out that a green "plátano macho" had a significantly higher carotene value than the rest.

OBJECTIVE

It was the purpose of this investigation to determine the content of carotene in green and ripe Puerto Rican plantains as sold to the consumer in different markets in the San Juan metropolitan area.

MATERIALS AND METHODS

Thirty-three different samples of totally green or ripe plantains, bought in different markets throughout the San Juan metropolitan area, were assayed for carotene using the standard chromatographic procedure recommended by the Association of Vitamin Chemists (13). Briefly it is as follows:

A representative sample of plantain containing about 250 μg. of carotene was weighed out. It was cut into small pieces and blended with acetone in a mechanical blendor. The acetone extract was transferred and the solid slurry remaining behind was mixed with a small quantity of water and blended again with petroleum ether until no color was extracted. The acetone extract, after adding some water, was also extracted with petroleum ether until no color was removed. All petroleum ether extracts were combined, dried over anhydrous Na_2SO_4, filtered, and concentrated to a volume of about 15 ml.

This concentrate was chromatographed in a column 2 to 2.5 cm. in length composed of a mixture of 1:1 of MgO and Super-Cel. The petroleum ether extract was poured into the column and suction was applied. After the chromatogram was developed it was eluated with a mixture of 3-percent acetone in petroleum ether until the desired pigments had moved off the column and the filtrate was colorless. The contents of the filtering flask were transferred to a volumetric flask and diluted by adding eluant to volume. The intensity of color was determined at 450 μ in a spectrophotometer. The calibration curve was prepared using carotene (B 90 percent, α 10 percent) diluted in eluant mixture. Concentrations ranging from 0.2 to 2.4 μg. per milliliter were used.

The results were expressed as micrograms (μg.) of carotene per gram of edible portion.

In order to use a different approach than the chemical assay, 28 day-old-white rats (Wistar-STM strain) were placed on the U. S. Pharmacopoeia (14) vitamin A-free diet. In a period of 4 to 5 weeks they showed signs of vitamin A deficiency such as cessation of growth and slight xerophthalmia.

Fourteen rats received a daily supplement of 0.2 mg. of the standard U.S.P. vitamin A acetate solution in oil, equivalent to 2 I.U. of vitamin A per day. Sixteen animals received as supplement 0.2 gm. of green plantain, and an equal number the same quantity of ripe plantain per day. An additional group of 16 animals were left as negative controls, receiving no supplement.

RESULTS

The average carotene content of the green plantain was found to be 10.43 μg. per gram of edible portion, while the ripe plantain contained only 6.68 μg. per gram. The difference between the two groups is highly significant, the value of t being 4.5, as shown in table 1.

TABLE 1.—*Carotene content of green and ripe plantains as determined by the chromatographic method*

Condition of plantain	Samples	Content of carotene as B carotene	Standard deviation	σ diff.	t
	Number	*μg. per gram*			
Green	33	10.46	3.66	0.82	4.5
Ripe	33	6.68	2.97		

TABLE 2.—*Rat-growth assay of green and ripe plantains*

Supplement fed	Animals	Supplement per day	Rats that died during the experimental period	Average gain or loss weight in 4 weeks
	Number	*Grams*	*Number*	*Grams*
U.S.P. standard vitamin A acetate	14	0.002[1]	[2]	28
Green plantain	16	.2	[2]	20
Ripe plantain	16	.2	4	11
Negative controls	16	[2]	12	−31

[1] Equivalent to 2 I.U. vitamin A per day.
[2] None.

Rat assay for provitamin A activity indicated that the green plantain protected the rats better than the ripe plantain. The standard test dose of 2 I.U. per day of vitamin A induced an average weight gain of 28 gm. in 4 weeks. Two-tenths of a gram of green plantain and the same quantity of ripe plantain, administered as a supplement daily to depleted rats induced weight gains of 20 and 11 gm., respectively, in a 4-week period (see table 2).

Although the difference of a 9-gm. gain in weight in favor of the green plantain was not statistically significant, the fact that four animals died

in the yellow-plantain group, and not a single animal died in the group receiving green plantain, is a further indication of the greater protective activity of the green over the yellow plantain. The samples of plantaind use in the rat assay were not the same ones used for chemical analyses.

SUMMARY

1. The carotene content of green and yellow plantains, as determined by the chromatographic assay procedure, averaged 10.43 ± 3.66 and 6.68 ± 2.97 μg. of carotene per gram of the raw edible portion, respectively.

2. Rat assay indicated that the green plantain protected more the vitamin A-depleted rats than the yellow plantain.

RESUMEN

1. El contenido de caroteno de los plátanos verdes y amarillos, según lo determinó el procedimiento que emplea el ensayo cromatográfico, fué 10.43 ± 3.66 y 6.68 ± 2.97 μg. de caroteno, respectivamente, por gramo de la porción comestible sin cocinar.

2. El ensayo con ratones de laboratorio indicó que el plátano verde podía proteger mejor a los ratones faltos de vitamina A que el plátano amarillo.

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Essentials of Successful Potato Culture in Puerto Rico

Juan Pastor Rodríguez and Pablo Landrau, Jr.[1]

INTRODUCTION

Several attempts have been made to establish potato culture in Puerto Rico on a commercial scale. Potatoes are not produced to any appreciable extent in the Island, although successful crops have been grown in certain regions of the highlands.

Potatoes constitute an important item in the diet of the Puerto Rican family, especially families of the middle class. Yet the Island depends almost entirely on importations for its supply of this important commodity.

According to the Annual Book of Statistics of the Commonwealth Department of Agriculture and Commerce, the average annual importations of potatoes for the 5-year period 1935–40 was 49,115,815 pounds, valued at $507,867. In 1951–52, the importations from the United States and foreign countries amounted to 79,195,000 pounds, valued at $1,997,000.

Of the 55,519 farms operating in Puerto Rico only 496 reported some land devoted to potato production. Of these, 336 farms reported plantings of less than 1 "cuerda."[2] Most of the potato production, therefore, is grown in small lots, mainly for home consumption.

Potato production, however, has not generally been profitable in the Island because of the diseases that attack this crop here—early blight (*Alternaria solani*), late blight (*Phytopthora infestans*), and bacterial wilt (*Pseudomonas solanacearum*)—and lack of experience in handling the harvested crop.

The people of Puerto Rico prefer locally grown potatoes, when available, to the imported old-crop potatoes. Consumers are always willing to pay a premium price for the locally grown potatoes. During war periods or stevedore strikes, the importations of potatoes have been almost negligible.

It has been found that good crops of potatoes can be produced in such highland locations as Orocovis, Barranquitas, Cidra, Adjuntas, Aibonito, and Cayey. However, prior to 1943–44, trials were never conducted in the rich coastal-lowland soils where sugarcane is grown under irrigation.

Potatoes have always been regarded by our agronomists as a potential crop to increase the Island sources of food supply. But before any recommendation could be made it was necessary to determine: 1, The best varieties for the highlands, where it is cooler; 2, the possibilities of growing

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[2] The Puerto Rican *cuerda* is equal to 0.9712 acre, or 42,305 square feet.

these in the lowlands under irrigation; 3, the degree of resistance to late blight of a number of promising varieties; and 4, proper storage conditions. This paper reports the results of the studies performed in connection with these factors.

PREVIOUS RESEARCH

In 1929 and 1930, (5)[3] the varieties Red Bliss Triumph, Irish Cobbler, Green Mountain, Smooth Rural, and Spaulding Rose No. 4, were imported into the Island for experimental purposes.

Satisfactory yields were obtained with some varieties such as the Bliss Triumph and Green Mountain. The tests, however, were not conclusive. Under Puerto Rican conditions these varieties are very susceptible to late blight and to bacterial wilt, and the crop must be cultivated under a well-controlled fungicide program.

In 1928–29 and 1929–30 Pedro Osuna and E. Molinary-Salés (6) conducted variety tests with the potato varieties mentioned above. An equal number of variety trials was located on level land in the mountainous regions of the Island and near the seacoast. The crops of the different varieties were harvested in from 74 to 82 days.

Tables 1 and 2 show the yields obtained by Osuna with the varieties Red Bliss, Irish Cobbler, Green Mountain, Smooth Rural, and Spaulding Rose 4.

The crops gave satisfactory results in some locations, but failed in others. Red Bliss Triumph and Irish Cobbler yields were highest. For the 2-year period studied Red Bliss Triumph appeared to be the outstanding variety, but there did not seem to be any statistical difference between the other varieties.

In a commercial planting with the Red Bliss Triumph in Villalba, at 800 feet above sea level, Ferdinand Méndez Roig obtained, in 1929, an average yield of 82 hundredweights of good large potatoes and 20 hundredweights of small potatoes per *cuerda*.

STUDIES OF THE NEWLY DEVELOPED VARIETIES

Le Clerge (3) reported that the new varieties of potatoes, Sebago and Red Warba, were resistant to late blight and could be grown in most seasons without spraying. These varieties and some others which had not been tested in Puerto Rico were imported to determine their adaptability.

Work in this connection began in 1943–44; it was conducted by Policarpo González Ríos until October 1, 1945, and then by Ferdinand Rochet, with the occasional collaboration of Félix Aróstegui, until 1947–48. From that date on the work was continued by the senior author of this article with

[3] Numbers in parentheses refer to Literature Cited, p. 170.

the collaboration of Arturo Riollano, A. Rodríguez Cabrera, José Adsuar, Luis Alvarez García, Lidy López, R. Gandía Caro, and Marcial Rico Ballester.

TABLE 1.—*Mean yields of potatoes in hundredweights per acre in 11 trials performed at different locations in 1929 and 1930*

Year and location	Yields of varieties indicated				
	Red Bliss Triumph	Irish Cobbler	Green Mountain	Smooth Rural	Spaulding Rose 4
1929					
Cidra	70	57	68	32	—
Comerío	89	61	65	32	46
Adjuntas	134	121	121	74	—
Do	89	61	65	31	46
Lares	109	89	107	59	86
Isabela	42	53	58	19	—
Average	89	74	81	41	59
1930					
Cidra	50	40	19	26	37
Comerío	85	99	50	51	97
Adjuntas	60	59	18	23	43
Do	50	50	18	38	35
Jayuya	95	76	71	43	89
Average	68	65	35	36	60

TABLE 2.—*Average yields and estimated coefficients of variability for the different varieties of potatoes grown during 1929 and 1930*

Variety	1929	1930	Average	Estimated coefficient of variability
	Cwt.	*Cwt.*	*Cwt.*	*Percent*
Red Bliss Triumph	89	68	79	5.5
Irish Cobbler	74	65	69	7.0
Green Mountain	81	35	58	7.2
Smooth Rural	41	36	39	8.1
Spaulding Rose 4	59	60	60	8.5

The work comprised: 1, Varietal trials; 2, the use of fungicidal chemicals; 3, the use of organic insecticides; 4, seedling tests; and 5, spacing and fertilizer trials.

VARIETY TRIALS

Such potato varieties as Katahdin, Sebago, Green Mountain, Red Bliss, Red Warba, Irish Cobbler, Placid, Virgil, Essex, and Kennebec were tested with and without irrigation in the highlands and in the lowlands.

Regions above 1,500 feet elevation above sea level were considered highlands and lower elevations were regarded as lowlands. The varieties were treated with fungicidal chemicals for the control of both early and late

FIG. 1.—Potato seedlings growing in boxes in the greenhouse.

blight, and also with the new organic insecticides for the control of aphids and other potato insects.

In the mountainous regions the sites selected were located at Orocovis, Adjuntas, Cidra, Corozal, and Aibonito. In the lowlands sites were selected at Río Piedras, Isabela, and Colonia Fortuna of the South Puerto Rico Sugar Co.

Tests of adaptability were carried out in collaboration with F. J. Stevenson, Principal Geneticist of U. S. Department of Agriculture at Beltsville, Md. Seedlings bred at Beltsville were sent to us by Dr. Stevenson to be tested under conditions here. These seedlings with "wild blood" in them (*Solanum demissum*, highly resistant or inmune to blight, and *S. poly-*

adenium, a tuberous Mexican species with good vigor inmune to blight), were supposed to be resistant to the early and late blight diseases.

The seedlings were started in boxes made *ad hoc* in the greenhouse (fig. 1) and were later transferred to the field. It seems that the organism causing the potato blight in Puerto Rico is more active or virulent than the ones to which these varieties are resistant, as most of the seedlings received were severely affected by the blights. To test the resistance of these seedlings to the blight organisms, they were not sprayed with any of the fungicidal chemicals. Such insecticides as DDT and nicotine sulfate were used to keep the potato seedlings free of aphids and of some of the insects that attack potatoes.

In January 1950, Dr. Stevenson sent seed tubers of seedlings identified as Kennebec, Huinkul, B. 75-4, and 46952. Of these, Kennebec has proved to be outstanding in resistance to blight and adaptability to Island conditions. Five hundred pounds of certified-seed tubers were imported from Maine for regional tests at Aibonito on upland soils, and at Isabela on the lowland. These plantings were treated in the same way as any commercial planting, with the exception of spraying for fungus diseases. The test at Isabela had irrigation water when needed, but the one at Aibonito depended on rainfall exclusively.

The following fungicidal chemicals were tried:

Trade name	*Active ingredient*
Bordeaux Mixture	Basic copper sulfate
Copper A Compound	Copper oxychloride
Dithane D-14	Disodium ethylene bisdithiocarbamate
Dithane Z-78	Zinc ethylene bisdithiocarbamate
Parzate	Do.
Phygon XL	Dichloronaphtoquinone
Fermate	Ferric dimethyl dithiocarbamate
Zerlate	Zinc dimethyl dithiocarbamate

The above chemicals (1) were, in general, solids insoluble in water, but they were readily suspended in water by the use of wettable agents. To avoid drifting of the chemicals from one plot to the other small hand-sprayers of the Vermorell type were used and spraying was accomplished when the wind was at a minimum. Weekly sprayings were made at all locations. The spraying was started as soon as the seed germinated and the first leaves showed above the soil, and continued until the crop was mature. Before harvesting the crop, the potato plants were sprayed with a solution of $CuSO_4$ in order to kill the mycelia and spores of the pathogen in the soil and in the aerial part of the plants, and thus avoid the contamination of the potato tubers while digging them out, as some of the harvested tubers were to be stored and kept for future plantings.

FERTILIZER-SPACING

When the new potato variety Kennebec became available combined fertilizer (2) and spacing experiments were conducted with it at Aibonito (2,000 feet above sea level), Isabela (275 feet above sea level), and Corozal (400 feet above sea level).

Five different spacings (6, 9, 12, 15, and 18 inches between plants in the row) and varying quantities (2) of nitrogen (N), phosphoric acid (P_2O_5), and potash (K_2O) were tried.

TABLE 3.—*Effects of fungicidal treatments to control early blight* (Alternaria solani) *in the Red Bliss Triumph potato grown at Cidra during the planting season Feb. 2–May 12, 1949*

Fungicide used	Mean yield in hundredweights per acre of potatoes, by size	
	Large potatoes	Large plus small potatoes
Zerlate	80	95
Parzate	72	89
Dithane Z-78	72	86
Copper A compound	68	82
Bordeaux mixture	68	84
Phygon XL	67	82
Check	61	76
Least significant differences at:	5-percent level—10.50 1-percent level—14.14	

EXPERIMENTAL RESULTS

VARIETY TRIALS

Decidedly the best time of the year to plant potatoes in Puerto Rico is early in winter. Then good yields were obtained at Orocovis, above 2,000 feet in elevation in the central part; and at Isabela, at 275 feet elevation, in the northwestern side of the Island. During the hot days of summer and autumn the yields were very low.

Despite the differences in climate the varieties showed a better adaptation to the conditions at Isabela (tables 3–9) in the coastal plain than at other locations at higher elevations. At this location the soil was of a much better texture for the production of potatoes and also had irrigation water when necessary. Here (winter season, 1946, table 3) the varieties Sebago, Green Mountain, Irish Cobbler, Red Bliss, and Essex had an average yield of 100 hundredweights per acre of No. 1 potatoes, Green Mountain and Sebago being the outstanding varieties. Aided by the frequent spraying, Red Bliss gave fairly high yields, notwithstanding its

high susceptibility to blight. In a commercial planting, the variety Kennebec yielded over 150 hundredweights per acre at Aibonito in the mountainous region, and at Isabela in the lowlands near the sea coast.

TABLE 4.—*Effects of fungicidal treatments to control early blight* (Alternia solani) *in the varieties Red Bliss Triumph and Irish Cobbler potatoes grown at Río Piedras during the planting season December 29–April 8, 1949*

Fungicide used	Mean yield in hundredweights per acre of potatoes for—	
	Red Bliss Triumph	Irish Cobbler
Zerlate	43	60
Dithane Z-78	40	59
Parzate	38	56
Bordeaux mixture	36	44
Copper A Compound	41	51
Check	37	58
Least significant differences at:		
5-percent level	3.86	4.17
1-percent level	5.17	6.30

TABLE 5.—*Mean yields in hundredweights per acre of different potato varieties tested at different locations and elevations in the Island during the spring months of 1944 and winter of 1946*

Variety	Spring season 1944–45				Winter season 1946–47		
	Río Piedras, below 1,500 ft.	Isabela, below 1,500 ft.	Ponce, below 1,500 ft.	Orocovis, above 1,500 ft.	Río Piedras, below 1,500 ft.	Isabela, below 1,500 ft.	Corozal, below 1,500 ft.
Katahdin	29	83	31	12	—	—	—
Sebago	20	81	20	7	52	130	35
Green Mountain	21	90	27	17	51	126	44
Red Warba	25	43	15	19	—	—	—
Irish Cobbler	25	77	25	20	40	114	29
Red Bliss	—	—	—	—	58	102	46
Placid	—	—	—	—	42	85	47
Essex	—	—	—	—	68	110	43
Least significant differences needed for comparison between any two means at:							
5-percent level	6.1	11.9	7.3	8.4	3.8	9.6	3.0
1-percent level	8.3	15.9	9.8	11.3	5.1	8.9	4.0

FUNGICIDAL CHEMICALS

Zerlate seemed to be the best fungicide for the control of early blight (*Alternaria solani*) at Río Piedras and at Cidras, (tables 3–4). As for late blight, (table 9) Copper A Compound, Bordeaux Mixture, and Dithane

TABLE 6.—*The effect of Bordeaux Mixture and Dithane for the control of blights, as indicated by yields in hundredweights per acre of different potato varieties tested during the winter, summer, and autumn of 1945–56 at various locations in the Island*

Variety	Isabela				Ponce, winter —sprayed with Bordeaux Mixture	Orocovis, winter —sprayed with Bordeaux Mixture	Adjuntas, winter —sprayed with Bordeaux Mixture	Río Piedras				
	Winter		Summer					Summer		Autumn		
	Not sprayed	Sprayed with Bordeaux Mixture	Not sprayed	Sprayed with Bordeaux Mixture				Not sprayed	Sprayed with Bordeaux Mixture	Not sprayed	Sprayed with Bordeaux Mixture	Sprayed with Dithane
Katahdin	47	74	22	43	25	61	29	8	6	21	23	19
Sebago	53	80	24	33	29	78	46	7	5	26	21	16
Green Mountain	65	107	41	42	36	85	39	5	6	17	15	15
Irish Cobbler	56	102	36	56	23	80	39	4	4	6	6	3
Red Bliss	77	127	32	30	28	74	59	.49	.71	20	26	18
L.S.D. at the:												
5-percent point	8.6	9.9	6.7	13.8	12.3	11	9.8	2.7	2.4	6.0	6.0	6.0
1-percent point	11.6	13.1	9.1	18.6	16.6	14.9	13.2	3.6	3.2	8.0	8.0	8.0

TABLE 7.—*Influence of spacing and major-element fertilizers applied at different rates on the yields in hundredweight per acre of potatoes in the Isabela, Aibonito, and Corozal trials*

Pounds per acre of—			Mean yields at—		
N	P_2O_5	K_2O	Isabela	Aibonito	Corozal
0	100	100	135	51	54
100	0	100	103	49	43
100	100	0	147	58	58
100	100	100	167	56	66
150	150	150	148	56	64
200	200	200	146	55	61
Least significant differences between any 2 general means of fertilizer treatments at:					
5-percent level			24.0	5.3	13.4
1-percent level			31.7	7.0	17.8

Z-78 proved to be equally effective to check late blight in a highly significant way.

The effect of a fungicide for blight control was very well shown in the Isabela trial 3 (table 5), where potato varieties Katahdin, Sebago, Green Mountain, Irish Cobbler, and Red Bliss sprayed with Bordeaux Mixture

TABLE 8.—*Influence of spacing and major-element fertilizers applied at difference rates per acre on yields in hundredweights per acre of potatoes in the Isabela, Aibonito, and Corozal trials*

Spacing between plants in the row (inches)	Mean yields of potatoes per acre for spacings indicated at—		
	Isabela	Aibonito	Corozal
	Cwt.	*Cwt.*	*Cwt.*
6	169	74	71
9	154	61	56
12	145	54	57
15	127	43	54
18	111	38	49
L.S.D. between:			
Any 2 general means of spacing treatments at the:			
5-percent level	23.2	7.5	17.0
1-percent level	32.5	10.5	23.9

TABLE 9.—*Effects of different fungicidal chemicals used for the control of late blight* (Phytophthora infestans) *on the yield in hundredweights per acre of the potato variety Red Bliss Triumph at Corozal, 1950–51*

Fungicide tested	Mean yield of potatoes per acre, by size		
	Large and small, 1950	Large, 1951	Large and small, 1951
Copper A Compound	83	43	63
Bordeaux Mixture	74	45	67
Dithane Z-18	72	37	58
Parzate	54	34	56
Check No. 1 (D.D.T. plus nicotine sulfate)	48	26	47
Zerlate	42	33	50
Phygon XL	35	39	60
Check No. 2 (No D.D.T. or nicotine sulfate)	34	23	47
Least significant difference needed for comparison between any two means at:			
5-percent level	16.6	13.8	15.8
1-percent level	22.4	18.6	21.1

produced increases of 26, 27, 41, 44, and 50 hundredweights, respectively, over the yields of the same varieties unsprayed.

COMBINED FERTILIZER AND SPACING TRIALS

Of the nutritive elements tried, phosphorus (table 5) proved to be the most limiting for potato production. The results were surprising and far superior at Isabela than at the other locations. Here, on a Coto clay soil,

with artificial irrigation, the potatoes made better use of the NPK combination than on the heavier Lares and Juncos clay of Corozal and Aibonito.

Some places the soils where the trials were located were suitable for growing potatoes, the preparation of the soil being relatively easy. In other localities the soil used were heavy and needed much plowing and harrowing before a suitable tilth was obtained. At Río Piedras, for example, the experiments were established on a Vega Baja silty clay (4), a moderately acid soil which occurs in a number of widely separated parts of the humid sections of the Island, where it occupies bordering areas between the alluvial and the coastal-plain soils. The soil of the sites chosen for the Isabela experiments was a Coto clay, an acid lateritic soil which occurs in nearly level areas derived from limestone of the tertiary formations. The experiment at Cidra was conducted on a Catalina clay, an acid, red, friable clay soil derived from andesitic tuffs and tuffaceous shales, prevailing in areas receiving more than 79 inches of average annual rainfall. This is the most extensive all-around farming soil of the uplands. The Corozal and the Orocovis experiments were planted on a Lares clay, a lateritic clay (pH 4.5) of the terrace and alluvial fans of Puerto Rico, cropped mainly to sugarcane and pineapples. The experiment at Colonia Fortuna at Ponce was planted on a San Antón silty clay, an alluvial soil located along the southern coast paralleling the streams but at a considerable distance from the riverbanks. The Aibonito experiments were established on a Juncos clay, an acid soil (pH 5.5) of the foothills that occurs in association with the extensive *Múcara* soils of the mountain areas of the Island and also in association with the soils of the valleys.

The planting distances for these trials varied from 12 to 18 inches between plants in the rows and from 24 and 36 inches between rows. In the fertilizer-spacing trial the spaces between plants were 6, 9, 12, 15, and 18 inches.

USE OF FUNGICIDAL CHEMICALS

The varieties under test were sprayed with different fungicidal chemicals to determine their effects on the yield of potatoes. In some instances checks were introduced with and without organic insecticides being used to control the aphids and other insects which are the vectors of the mosaic disease.

SUMMARY

Potatoes constitute an important item in the diet of the Puerto Rican family. Large amounts of this important commodity are imported to the Island every year, and for this reason it has always been regarded by our agronomists as a potential crop to increase the Island sources of food supply.

But, before it could become an established crop in Puerto Rico, the optimum conditions in other respects than varieties had to be determined.

Potato trials were conducted under different conditions of soil and climate to find the best way to manage the different factors which are essentials for the successful production of potatoes in the Island.

1. The use of fungicidal chemicals for the control of early and late blights demonstrated that when properly used, such fungicides as Zerlate and Parzate are effective for the control of early blight, and that Copper A Compound, Bordeaux Mixture, and Dithane Z-78 are equally effective to check late blight.

2. Variety trials were conducted at different places in the highlands and lowlands with the commercial varieties Katahdin, Sebago, Green Mountain, Red Warba, Irish Cobbler, Red Bliss, Placid, Essex, and Kennebec. The high-yielding potato variety Kennebec proved to be highly resistant to blights, and gave good yields. Good production could be obtained also with the other varieties mentioned above if blight was fully controlled.

3. Better yields were obtained when the varieties were planted early in the winter season than when they were planted in the summer season.

4. The best yields were obtained when the potatoes were spaced 6 to 9 inches between plants in rows spaced 24 to 30 inches apart.

5. Phosphorous was the most essential fertilizer element to increase the potato yields under the conditions of the trials conducted.

6. Winter appeared to be the best time of the year for the planting of potatoes.

Here also over 150 hundredweights of large potatoes were obtained when the potatoes were spaced 6 and 9 inches between plants (table 6) in the row. The potatoes grown at Isabela were twice the size of those from Aibonito and Corozal (figs. 2 and 3) a great many of them weighing over 12 ounces. At Aibonito and Corozal, where we had to depend on rainwater for the potatoes to grow, the rainfall was rather scanty during the growth period, thus limiting the yields considerably.

The work with distance between plants (table 6) showed great differences in yield of potatoes. The highest yields were obtained when the potatoes were spaced 6 inches between plants in the row.

The yields in the spacing-fertilizer trial (table 7) were affected by the climate. In Aibonito, because of abnormal rainy conditions, the seed had to be planted late, hence the sprouted seed tubers had to be kept for a longer time in the barn.

At Corozal the conditions were fairly good at time of planting, but a long drought during the growing period adversely affected the production. At Isabela, production was much better in a looser soil, where a more

FIG. 2.—Potato variety trial at Isabela Substation. The foreground plants in bloom belong to the Kennebec variety.

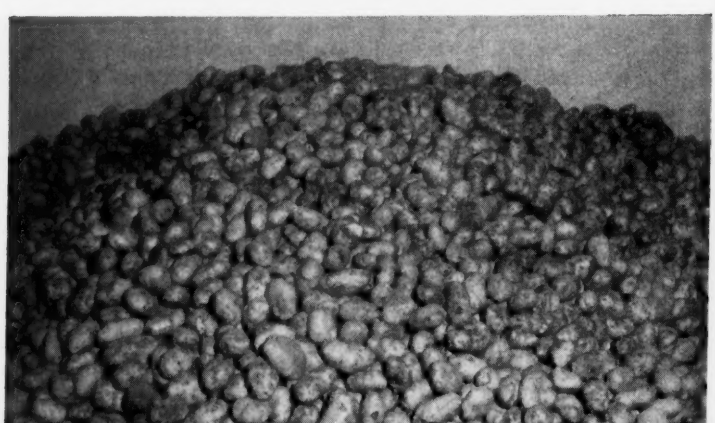

FIG. 3.—Kennebec potatoes in the field immediately after harvesting and before classification at the Isabela Substation.

favorable climate prevailed during the growth period. Here also there was sufficient irrigation water.

A highly significant correlation was obtained between number of potato seed pieces planted per acre and yield in the experiments at the different locations.

It seems that under normal climatic conditions and with good management and fertilizer practices the variety Kennebec will yield reasonable crops of good No. 1 potatoes when plants are spaced 6 to 9 inches apart in the row (table 6).

It is well to say here that the potato demands a good loose texture in the seedbed and sufficient moisture in the soil for maximum production. In Puerto Rico some of the soils used in the research work with potatoes were heavy and needed much plowing and harrowing. Where a good loose seedbed could not be obtained and the rainfall was scanty the potatoes did not grow well and the yields were very low.

RESUMEN

La papa es un alimento de gran importancia en la dieta de una buena parte de la familia puertorriqueña, la clase media. Todos los años se importan al país grandes cantidades de papa y por esta razón este producto ha sido siempre considerado por nuestros agrónomos como una cosecha de gran valor potencial. Su siembra en escala comercial no hay duda que aumentaría en la Isla el tan necesario abastecimiento continuo de alimentos. Pero antes de que su cultivo pudiera establecerse en Puerto Rico se necesitaba determinar las condiciones óptimas ambientales para su mejor desarrollo, como también saber cuáles son las mejores variedades adaptables a la Isla.

Se llevaron a cabo distintos experimentos bajo diferentes condiciones de suelo y clima con el propósito de resolver diferentes problemas de campo y ver cuáles son los factores que limitan el éxito de la producción de la papa en la Isla.

Los resultados de estos experimentos indicaron lo siguiente:

1—La aplicación de fungicidas para controlar los tizones tempraneros y tardíos demostró que el Zerlato y el Parzato son eficaces para controlar el tizón temprano. El Compuesto A de cobre, el caldo bordelés y el Ditano Z-78 dan iguales resultados en cuanto al tizón tardío.

2—En distintos sitios de la altura y la bajura de Puerto Rico se llevaron a cabo ensayos con las variedades Katahdin, Sebago, Green Mountain, Red Warba, Irish Cobbler, Red Bliss Placid, Essex, y Kennebec. Esta última variedad fué más resistente al ataque del tizón y produjo buenas cosechas tanto en la altura como en la bajura. También se lograron buenas cosechas de las otras variedades arriba mencionadas cuando se pudo con-

trolar totalmente el tizón. De estas variedades las Green Mountain, Katahdin, Sebago y Essex dieron los mejores rendimientos.

3—La producción mayor se logró de las siembras hechas durante el principio del invierno.

4—Todas las variedades produjeron más cuando la semilla se sembró de 6 a 9 pulgadas de distancia en los surcos y de 24 a 30 pulgadas entre surcos.

5—El fósforo fué el elemento fertilizante más esencial para aumentar los rendimientos, bajo las condiciones en que se llevaron a cabo estos experimentos.

6—El invierno parece ser la mejor estación del año para la siembra de la papa en Puerto Rico.

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Identification of the Anthocyanin Present in the Acerola which Produces Color Changes in the Juice on Pasteurization and Canning

Rafael Santini, Jr., and Alice Huyke[1]

INTRODUCTION

Acerolas have been shown by Asenjo and Freire de Guzmán (1),[2] to be a good natural source of ascorbic acid. The ascorbic acid content of the juice suffers little change when the juice is pasteurized and canned (2, 3). However, the acerola juice darkens and there is a concurrent loss of flavor on pasteurization and canning.

After pasteurization the deep bright-red color of the acerola juice changes to yellowish and, upon standing several months at room temperature, it becomes brown and CO_2 gas, which causes swelling of the cans, is produced. This change in color limits the usefulness of the acerola juice and it was felt that there was need of determining its cause.

PROCEDURE

The following evidence suggested that the red color present in the acerola juice was caused by an anthocyanin pigment: 1, The spectrophotometric curves of the juice shown in figure 1 display an absorption band between 500 and 220 mμ (4). 2, An isobutyl alcohol extract of the fruit shows the characteristic anthocyanin blue-purple band at the top of a chromatographic column filled with activated alumina (6).

The method used by Sondheimer and Kertesz (4) for the isolation and crystallization of the anthocyanin pigment present in strawberries was adapted for the acerola and may be summarized as follows: Frozen acerolas were pressed after they had thawed sufficiently at room temperature. The 50 l. of juice obtained were saturated with sodium chloride. The NaCl-saturated juice was divided into 5-l. portions and each portion was extracted with 1.25 l. of butanol. The butanol extracts were combined and concentrated *in vacuo* to about 1,000 ml. The crude pigment was precipitated by the addition of 5 l. of anhydrous ether. After standing for about 2 hours, the supernatant liquid was filtered and discarded. The precipitate was washed several times with 300-ml. portions of anhydrous ether. The yield of crude concentrate was 20 gm. The granular pigment was dissolved

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[2] Numbers in parentheses refer to Literature Cited p. 178.

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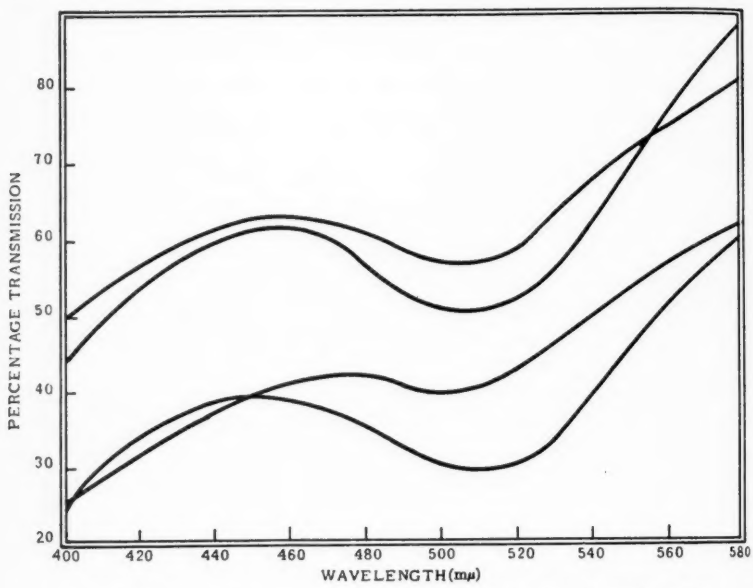

FIG. 1.—Absorption curves of 4 different samples of fresh acerola juice.

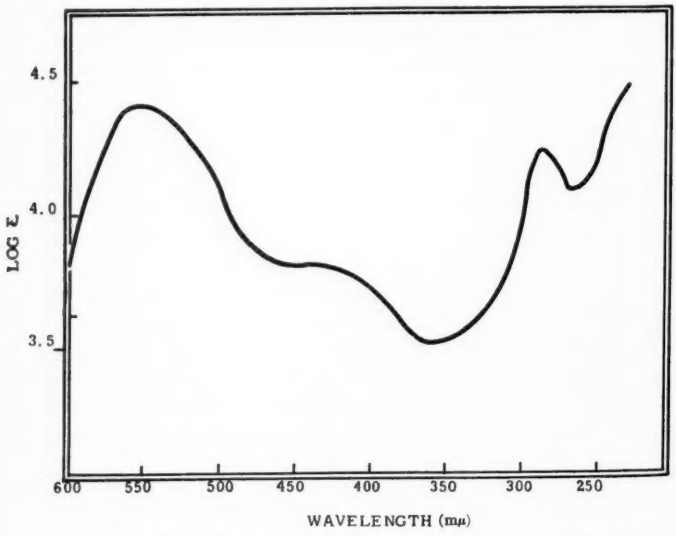

FIG. 2.—Absorption curve of the anthocyanin isolated from acerola juice.

in 500 ml. of 0.01-percent HCl, filtered, saturated with picric acid, and stored at 0°C. for 48 hours.

The crude-picrate preparation was completely soluble in 50 ml. of ethanol, containing 5 percent of HCl. One liter of anhydrous ether precipitated flocculent anthocyanin chloride. After standing 2 hours at 0°C., the mixture was filtered and the precipitate thoroughly washed with ether. This preparation was still impure and was therefore reconverted first to the picrate and then to the chloride. The purified chloride was dissolved in 4 ml. of methanol and 1.5 ml. of 12-percent HCl were added. This solution was allowed to evaporate at room temperature. After 24 hours the crystals of the anthocyanin were obtained and were dried at 50°C. for 2 hours. The final yield of the crystalline anthocyanin was 800 mg.

TABLE 1.—*Color reactions of the anthocyanin obtained from the acerola and of malvidin chloride in buffered solutions of different pH values*

pH of the buffer solution	Anthocyanin obtained from the acerola	Malvidin chloride
3.8	Bluish red; changes to pink and quickly decolorizes	Bluish red; changing rapidly to pink and quickly decolorizing
6.0	Violet	Violet, fading slowly
7.0	Violet blue	Violet blue
8.0	Blue	Blue
10.4	Blue, changing to greenish blue	Blue, changing to greenish blue
11.8	Blue, fading rapidly to pale green	Blue, fading rapidly to pale green

RESULTS

The absorption curve of the anthocyanin crystallized from the acerola shown in figure 2 was obtained with a Beckman Spectrophotometer, Model DU, using 1-cm. quartz cells. The molar-extinction coefficients were calculated and plotted against the wavelength. The curve is identical with that obtained for delphinidin, malvidin, and hirsutidin (7, 8).

The anthocyanin obtained was slightly soluble in water, giving a red-violet solution. It reduced Fehling's solution when boiled, and first gave a violet solution with sodium hydroxide which, upon addition of more sodium hydroxide, changed to greenish-blue. The color disappeared from the very dilute solution when heated. All these properties are identical with those listed for hirsutin and malvin (7).

Although the melting points of anthocyanin are accompanied by decomposition and are of no value for identification purposes (8), it was decided to run several melting-point determinations. No melting point

was obtained with the anthocyanin crystallized from the acerola when heated above 300°C. This agrees with the information found in the literature for malvin chloride (9).

TABLE 2.—*Changes in ascorbic acid, red coloration, and optical density of different samples of acerola juice when stored at room temperature*

Sample and age of juice in days	Ascorbic acid per 100 ml. juice	Red color as Congo Red per 100 ml. juice	Optical Density 420 mμ
	Gm.	*Mg.*	
Sample I:			
0 (fresh)	1.442	3.70	0.235
0 (after pasteurization)	1.440	1.90	.249
3	1.404	.85	.345
5	1.343	.40	.385
8	1.329	.10	.398
11	1.312	0	.435
18	1.274	0	.540
30	1.264	0	.580
60	1.177	0	.740
Sample II:			
0 (fresh)	1.025	3.10	.215
0 (after pasteurization)	1.014	1.15	.365
3	.993	.40	.450
6	.962	0	.495
14	.914	0	.750
30	.877	0	.780
60	.806	0	.850
Sample III:			
0 (fresh)	1.257	5.50	.225
0 (after pasteurization)	1.254	2.20	.310
3	1.247	.75	.410
10	1.174	0	.518
30	1.122	0	.690
60	1.061	0	.730
Sample IV:			
0 (fresh)	1.342	3.50	.228
0 (after pasteurization)	1.318	1.40	.300
3	1.261	.35	.350
10	1.220	.20	.445
30	1.168	0	.565
60	1.108	0	.670

The examination of the reaction of anthocyanins on a range of buffered solutions has shown that this method is by far the most reliable for purposes of comparison and characterization (8).

Buffered solutions were prepared at different pHs. The colors obtained

(table 1) were identical with those found in the literature for malvidin chloride (10).

Several samples of acerola juice were prepared and stored at room temperature and 0°C. for 2 months. Data on the ascorbic acid content, red coloration, and optical density at 420 mμ were obtained and are shown in tables 2 and 3.

The method used for the quantitative determination of the red color in the strawberries (5) was adapted for the acerola and may be summarized as follows: Measuring the light absorption of the juice at 500 mμ and at pHs

TABLE 3.—*Changes in ascorbic acid, red coloration, and optical density of different samples of acerola juice when stored at 0°C.*

Samples and age of juice in days	Ascorbic acid per 100 ml. juice	Red color as Congo Red per 100 ml. juice	Optical density 420 mμ
	Gm.	*Mg.*	
Sample I:			
0	1.442	3.70	0.235
3	1.417	3.70	.220
5	1.387	2.95	.210
8	1.361	3.10	.190
11	1.360	2.30	.200
18	1.360	2.20	.210
30	1.354	2.25	.190
60	1.351	2.00	.210
90			
Sample II:			
0	1.342	3.60	.228
3	1.235	3.65	.180
10	1.234	3.10	.160
24	1.237	3.65	.190
60	1.136	2.45	.240

of 3.40 and 2.00. The measurement consisted of substracting the optical density at 500 mμ of juice at a pH of 3.4 from its optical density at a pH of 2.00, at a known concentration. The increase in color intensity under such conditions is proportional to the concentration of red color in the solution. A solution of Congo Red, which follows Beer's Law (fig. 3) was used as a standard of color intensity and the results are expressed as milligrams of Congo Red per 100 ml. of juice.

The ascorbic acid content was determined by the iodate method (11).

The increase in the darkening of the juice was determined by measuring the optical density at 420 mμ (12) in samples of juice at a known concentration.

Figure 4 shows how the absorption band obtained at 520 mμ in fresh acerola

juice decreased in intensity after pasteurization and disappeared during storage at room temperature. The change was not so rapid in frozen juices (fig. 5). This agrees with the values obtained in the quantitative determination of red color given in tables 2 and 3.

DISCUSSION

It has been shown in table 2 that the ascorbic acid decreased and the red color disappeared in juices stored at room temperature, while the optical

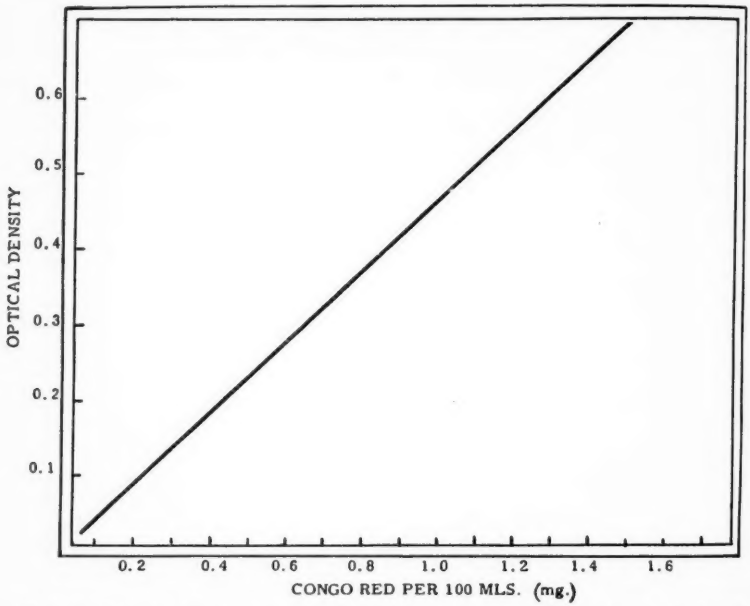

FIG. 3.—Standard transmission-concentration curve prepared using a solution of Congo Red in 0.01 N Na_2CO_3 .

density at 420 mμ increased. In frozen juices (table 3) the amount of ascorbic acid and of red coloration decreased less rapidly, while the optical density either remained constant or decreased, and no brown color was observed in these juices during the storage period.

All evidence presented in this paper suggests that two main types of nonenzymatic reactions occur in the acerola juice. In one the red color is lost and in the other secondary brown pigments develop.

The data presented in tables 2 and 3 suggest that ascorbic acid is probably one of the constituents participating in the reaction taking place, as

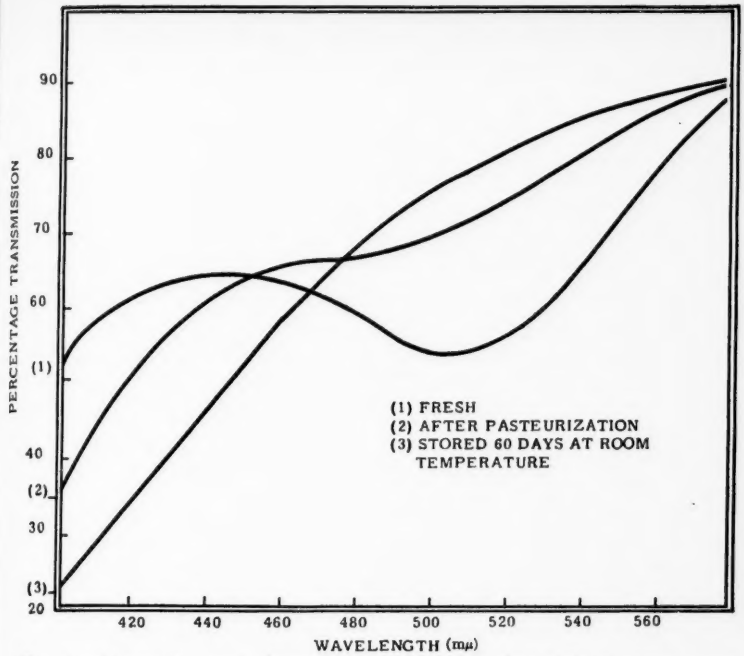

FIG. 4.—Absorption curve of a sample of acerola juice when fresh, after pasteurization, and after storage at room temperature for 60 days.

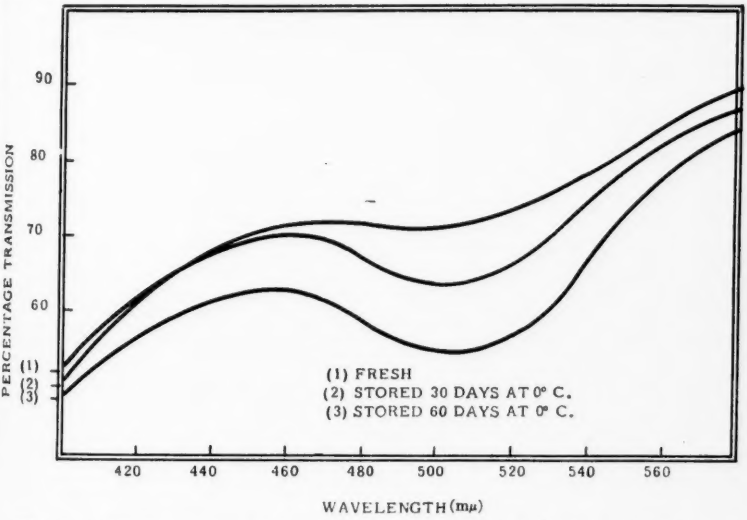

FIG. 5.—Absorption curve of a sample of acerola juice when fresh and after storage at 30 and at 60 days at 0°C.

has been suggested by others (6, 13 and 14) in their work with strawberry juice.

SUMMARY

The bright red color of the expressed juice of the acerola changed to yellowish after pasteurization and, upon standing 2 months at room temperature, to brownish, and CO_2 gas was produced, with subsequent swelling of the cans. Frozen juices stored for the same period remained red in color.

A method for isolating and crystallizing the anthocyanin pigment present in the acerola juice has been described. Evidence has been presented which shows that this anthocyanin is malvin.

Data presented in this paper suggest the possibility of two nonenzymatic reactions occurring in the acerola juice and the possible participation of ascorbic acid in these reactions.

RESUMEN

El color rojo brillante del jugo de acerola cambia inmediatamente después de pasteurizar a un color rojo-amarillo. Después de almacenado por dos meses a temperaturas atmosféricas ordinarias, el color cambia a pardo y produce CO_2. En jugos congelados que han estado almacenados por el mismo período, el color se ha mantenido rojo.

Se describe el método para aislar y cristalizar la antocianina presente en la acerola. Esta antocianina ha sido identificada como malvina.

Los datos experimentales obtenidos de este trabajo nos sugieren la posibilidad de dos reacciones químicas que ocurren en el jugo de acerola y la posible participación del ácido ascórbico en estas reacciones.

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Some Limitations in the Use of the Air Picnometer for Soil-Porosity, Soil-Moisture, and Particle-Density Determinations

José Vicente-Chandler, Servando Silva, and Jacinto Figarella[1]

INTRODUCTION

The air picnometer has been rather widely used in determining the porosity of soils (4, 6, 7, 8, 11, 12)[2]. Some investigators (4, 7, 11) have proposed using the air picnometer to determine soil particle density and soil-moisture content. Jamison (3) has recently shown that this instrument cannot be used accurately to determine the particle density of dry soil since gaseous adsorption occurring on the surface of dry soil colloids can introduce a considerable error in these determinations.

OBJECTIVE

The purpose of this paper is to present the results of a study aimed at determining the adaptability of the bellows-type air picnometer to soil-porosity, soil-moisture, and particle-density measurements as compared with standard methods. The possibility of using moist soil in picnometric determinations to avoid the error introduced by gaseous adsorption on dry colloids was explored.

METHODS USED

Precautions were taken to make sure that the measurements with the air picnometer were as accurate as possible. The apparatus was constantly checked for leaks and was recalibrated periodically, since some variation was found to occur with usage. Readings were taken exactly 30 seconds after complete compression of the bellows. Different curves were prepared for use at varying atmospheric pressures.

PARTICLE-DENSITY DETERMINATIONS

Determinations were made by the standard picnometer-bottle method using both water and nitrobenzene. Oven-dried soil cooled in a desiccator was used. To insure complete saturation of all voids with liquid the procedure recommended by Smith (10) was followed.

Gentle boiling at 80°C. in a partial vacuum was tested as a further means

[1] Project Supervisor, Physical Science Aid, and Soil Scientist, respectively, of a cooperative Project between the Agricultural Experiment Station of the University of Puerto Rico, Río Piedras, P.R., and the Agricultural Research Service of the U. S. Department of Agriculture.

[2] Numbers in parentheses refer to Literature Cited, p. 188.

of insuring complete saturation of the soil pores with both nitrobenzene and water. Essentially the same results were obtained as with the method recommended by Smith.

The particle density of the soils studied was also calculated from determinations made with the air picnometer on moist and on oven-dried soil cores. In the former case the necessary corrections for the space occupied by water were made by calculating the volume of water from the loss in weight of the cores upon oven-drying and assuming the density of water to be 1.

POROSITY DETERMINATIONS

Undisturbed 3-inch x 3-inch (348 cc.) soil cores were used in these studies. Bulk densities were calculated from the dry weight of soil in the cores. The total porosity of the cores was calculated from their bulk densities with a particle density of 2.56 assumed.

The total porosity of the cores was determined with the air picnometer by measurements on oven-dried samples and on cores as brought from the field. In the latter case the volume of water (determined by loss in weight upon oven drying) was taken into consideration in calculating the total porosity of the cores.

SOIL-MOISTURE DETERMINATIONS

The moisture content of 26 undisturbed soil cores from three soil series was determined with the air picnometer, and by loss in weight upon oven-drying. The following formula was used to calculate the soil moisture content of the soil cores from measurements with the air picnometer:

$$\text{Percentage of moisture by weight} = \frac{100\ (\text{part. den. (cc. solids + liquid)} - \text{(gm. solids + liquid)}}{\text{part. den. (gm. solids + liquid)} - \text{(cc. solids + liquid)}}$$

OTHER DETERMINATIONS

The above studies indicated that considerable air dissolved in soil moisture in the course of determinations with the air picnometer on wet soils. This caused appreciable errors. An attempt was therefore made to determine the effect of soil-moisture content on picnometric determinations. The soil cores studied were saturated with water and then allowed to dry slowly in air. They were weighed periodically and picnometric determinations were made. The cores were finally oven-dried, cooled, weighed, and determinations made with the air picnometer. From these data the apparent

total porosity and quantity of air "sorbed"[3] by the soil samples at various moisture contents were calculated.

EFFECTS OF AIR-WATER INTERFACE

From the above study it appeared likely that area of air-water interface was one of the main factors affecting the extent of gaseous solution in soil moisture. In an attempt to test this hypothesis, Domby[4] carried out a study with two soils to determine the effect of soil structure and air content on the apparent volume of soil-plus-water, as measured by the air picnometer. Samples having equal quantities of soil and water were compressed to different overall volumes, thus varying both structure and the amount of air-water interface.

SOILS USED

Four soil types were included in this study. Catalina clay is a deep-red, acid kaolinitic soil (latosol) derived from andesitic tuff and tuffaceous shale. Coto and Fajardo clays are similar soils derived from hard limestone and outwash from shale hills, respectively. Toa loam is a slightly acid, deep, alluvial soil with predominantly expanding lattice-type clay minerals.

RESULTS

Results of particle-density determinations on samples of three soils by the methods described above, together with some related soil properties, are shown in table 1. The particle densities obtained in nitrobenzene varied little from the value (2.65) frequently assumed for most soils. The values obtained with water were higher in all cases. Those obtained by the air-picnometer method with both moist and oven-dry soils were much too high in all cases.

Total-porosity values of the soil cores as determined by the methods described are shown in table 2. The values calculated from bulk-density and particle-density data (assuming a value of 2.65 for particle density) are considered to be correct. The porosity values obtained by the air-picnometer method with both moist and dry soil cores were too high in all cases.

The results of the soil-moisture determinations indicate that the values obtained with the air picnometer were, with three exceptions, within 5 percent of the values determined by oven-drying.

Table 3 shows the results of the study to determine the effect of variable moisture content on picnometric determinations. At all moisture levels the

[3] This term is herein used to indicate air adsorbed on dry colloids, dissolved in soil moisture, or otherwise unaccounted for.

[4] Charles W. Domby, deceased, formerly Soil Scientist, Agricultural Research Service, USDA.

total porosities of the cores, as determined with the air picnometer, were much higher than the calculated values. Considerable air was "sorbed" at all moisture levels. There was no apparent relationship between moisture content and total porosity or amount of "sorbed" air.

The results of the study to determine the effect of percentage of air volume and soil structure on picnometric determinations are summarized in table 4. The data indicate that as wet soils are compressed, decreasing their air content and air-water interface, there is less "sorption" of air, and picnometric determinations are therefore more precise.

TABLE 1.—*The particle density of several soils of Puerto Rico as determined by various methods*

Soil and sample No.	Clay	Organic Matter	Particle density as determined by methods indicated				
			Picnometer bottle and nitrobenzene	Picnometer bottle and water	Air picnometer with oven-dried soil	Air picnometer with moist soil	Moisture by volume
	Percent	*Percent*					*Percent*
Catalina:							
1	46.2	2.61	2.66	2.71	3.32	3.11	44.2
2	64.2	4.20	2.61	2.75	3.26	3.05	42.3
3	54.3	3.48	2.63	2.70	3.47	3.16	42.6
4	55.6	3.94	2.65	2.74	3.37	3.04	43.2
5	46.1	3.81	2.66	2.71	3.34	2.94	30.2
Coto:							
1	72.0	3.20	2.64	2.74	3.10	2.92	30.0
2	75.0	3.01	2.61	2.73	2.98	2.88	24.9
3	68.0	3.50	2.60	2.72	3.32	3.26	22.7
Toa:							
1	30.8	4.58	2.62	2.64	3.33	3.06	49.4
2	26.1	3.55	2.65	2.66	3.25	3.10	45.8

DISCUSSION OF RESULTS

The fact that higher particle-density values were obtained in water than in nitrobenzene, a nonpolar liquid, is in close agreement with the findings of Anderson and Mattson (2) and, in general, with those of Smith (10) and Jamison,[5] although the differences found by the latter two were considerably smaller. The differences between the results obtained with water and with nitrobenzene may be explained by orientation and consequent "packing" of the dipole water molecules on the surface of soil colloids (2, 8) or by failure to fill all the soil pores with nitrobenzene (5). In view of the pre-

[5] Personal communication of Vernon C. Jamison, Soil Scientist, Agricultural Research Service, USDA.

TABLE 2.—*Total porosity of undisturbed cores from 4 Puerto Rican soil types as determined by various methods*

Soil and sample No.	Bulk density	Total soil porosities obtained from—		
		Bulk-density and particle-density data	Air-picnometer determinations on dry cores	Air-picnometer determinations on moist cores
Catalina:				
1	1.20	54.7	59.5	60.3
2	1.25	52.8	55.5	63.8
3	.92	65.2	67.5	69.2
4	1.05	60.4	65.5	65.0
5	1.22	54.0	57.5	58.7
6	.93	64.9	66.5	70.8
7	1.05	60.4	66.5	63.2
8	1.14	56.9	62.7	61.5
9	.99	62.6	67.5	64.7
10	.78	70.6	71.0	74.0
Average	1.05	60.2	64.0	65.1
Coto:				
1	1.10	58.5	68.0	61.6
2	1.27	52.1	63.0	58.8
3	1.11	58.1	68.0	64.0
4	1.28	51.7	62.8	63.5
5	1.09	58.9	68.5	65.4
6	1.17	55.8	65.7	67.7
7	1.08	59.2	69.0	65.0
8	1.25	52.9	63.0	60.6
9	1.07	59.6	69.0	65.6
10	1.33	49.8	60.0	56.4
Average	1.17	55.7	65.7	62.9
Toa:				
1	1.14	57.0	65.5	62.6
2	1.11	58.1	65.7	65.0
3	1.13	57.3	65.7	64.4
4	1.03	61.1	70.0	66.4
5	1.07	59.6	67.0	65.5
6	1.13	57.3	67.0	66.0
7	1.11	58.1	66.5	65.3
8	1.07	59.6	68.5	65.4
9	1.11	58.1	66.5	64.5
10	1.21	54.3	64.5	59.0
Average	1.11	58.0	66.7	64.4

TABLE 2.—*Continued*

Soil and sample No.	Bulk density	Total soil porosities obtained from—		
		Bulk-density and particle-density data	Air-picnometer determinations on dry cores	Air-picnometer determinations on moist cores
Fajardo:				
1	1.18	55.5	65.0	60.3
2	1.15	56.6	67.0	62.5
3	1.18	55.5	65.5	60.8
4	1.19	55.1	64.8	59.7
Average	1.17	55.7	65.6	60.8

cautions taken to assure complete saturation of the samples, the former explanation appears to be more plausible and the results with nitrobenzene more accurate.

The data seem to indicate that the kaolinitic soils high in clay content (Coto and Catalina) are capable of adsorbing water to the extent of about 1 percent of their weight. The high wilting points (1) found with these soils tend to lend further credence to this assumption. The relatively low particle-density values obtained in water with Toa soil may be explained by the low clay content of this soil, although it is of the expanding lattice type. Also, this type of clay may retain appreciable moisture even after drying at 105°C. Thus, a given quantity of clay may have no more "effective" surface on which the water added in the picnometer could be "packed" than would an equal amount of kaolinitic clay.

The high particle-density and total-porosity values obtained by the air-picnometer method using dry soil may be explained by gaseous adsorption on the surface of dry soil colloids while under pressure in the air picnometer, as shown by Jamison (3). Calculations made from these data indicate that an average of about 8 cc. of air were "sorbed" per 100 gm. of soil. This results in a lower volume of soil as determined by the air picnometer, and consequently in apparently higher particle densities and total porosities.

The particle-density and porosity values obtained by the air-picnometer method with moist soil cores, although generally somewhat lower than those obtained with dry soil, are still far too high. There appear to be two likely reasons for this. First, there may be considerable solution of air in soil moisture while under pressure in the air picnometer, resulting in errors analogous to those caused by gaseous adsorption on dry colloids. Calculations indicate that an average of about 5.5 cc. of air were "sorbed" per 100 gm. of soil. Second, in correcting for the space occupied by water, the volume occupied by this liquid is calculated from weight data using a density

value of 1, although the actual density may be greater due to orientation of the water molecules on colloidal surfaces, as discussed previously. Thus, the volume of water is overestimated, resulting in higher particle-density

TABLE 3.—*The apparent*[1] *total porosity of and gaseous "sorption" by a Catalina clay soil at varying moisture contents as determined with the air picnometer*[2]

Item	Results for soil of the indicated percentage moisture content, by volume—						
	Oven-dried	16.4	27.6	36.4	39.8	45.3	49.3
Apparent porosity.....percent	64.2	64.8	61.9	61.7	63.3	63.4	64.1
Air "sorbed" per 100 gm. of soil..cc.	7.0	7.5	5.0	4.9	6.2	6.3	6.9

[1] True total porosity as calculated from bulk and particle-density data = 55.8.
[2] All values are averages of 20 samples.

TABLE 4.—*The effect of soil structure and percentage air-filled pore space on apparent volumes of soil-plus-water, "sorbed" air, and soil-particle density, as determined by the air picnometer on two clays*[1]

Soil and volume weight	Air in soil by volume	True volume, soil-plus-water	Apparent volume soil-plus-water, by air picnometer	"Sorbed" air per 100 gm. soil	Particle density of soil as determined with air picnometer
	Percent	*Cc.*	*Cc.*	*Cc.*	
Hurricane clay, 44-percent moisture by weight:					
0.50	59.5	190.4	179.8	4.50	3.08
.78	36.8	190.0	183.4	2.80	2.92
1.21	2.4	189.3	190.8	.62	2.66
Decatur clay 18-percent moisture by weight:					
1.05	42.2	271.9	264.5	1.51	2.83
1.25	31.3	271.9	265.8	1.22	2.80
1.41	22.2	271.8	267.7	.83	2.77
1.69	6.4	271.7	268.9	.63	2.76

[1] Unpublished data obtained by Charles W. Domby. All values are means of 5 replicates. Differences in apparent volume, "sorbed" air, and particle density are significant at the 1-percent level.

and total-porosity values. It should be noted, however, that the magnitude of the error thus introduced is small.

The only likely error in the porosity values calculated from bulk-density and particle-density data lies in assuming a particle density of 2.65. In

any case, the error is small since, even considering extreme values (2.60 and 2.75), the variation is only about 2 percent of the pore space.

There is appreciable variation in the soil-moisture values as determined with the air picnometer and those obtained by oven-drying the samples. However, values generally fell within 5 percent of those obtained by oven-drying. By calibrating the instruments for the different soils and by taking a sufficient number of samples, this method would seem to be accurate enough for many types of fieldwork. It would appear to be particularly useful when the approximate moisture level of a soil has to be determined immediately in the field.

As mentioned previously, solution of air in soil moisture while under pressure in the air picnometer would appear to be a reasonable explanation for the high porosity and particle-density values obtained with moist cores. The fact that the data in table 3 show no clear relationship between moisture content and apparent total porosities or gaseous "sorption" is not surprising, since other factors probably mask any relationship of this nature.

It appears likely that area of air-water interface is important in determining the extent of gaseous solution in water. Since the area of contact between water and air is proportionately greater at low moisture contents, this factor alone would greatly obscure any relationship between quantity of water and extent of gaseous solution.

The data obtained by Domby (table 4) appear to indicate that, as the percentage air volume is reduced by compression of the samples, thus decreasing the area of air-water interface, gaseous solution in soil moisture decreases markedly, resulting in more precise values for particle density as determined with the air picnometer. These data thus seem to indicate that the area of air-water interface is important in determining the extent of gaseous solution in soil moisture while under pressure in the air picnometer. Since the significant effect of compression disappeared when the soils were oven-dried, it appears that the distribution of soil moisture and not of the solid soil was the important factor.

There is another possible source of variation in picnometric determinations. Air trapped in blocked pores in the wet, compacted samples might have failed to change pressure during the picnometric measurements. Compression of trapped air must occur as a result of soil-moisture movement which is slow in compact samples. Also the pressure applied in the picnometer is low (about 0.4 atmosphere). Trapped air which did not change pressure would tend to give higher picnometer readings, thus compensating for the error caused by gaseous sorption and resulting in values that are closer to correct for particle density.

SUMMARY

The air picnometer does not appear to be suitable for accurately determining either the particle density, the porosity, or the moisture content of soil samples. However, it appears well suited to making rapid, approximate field estimates of soil porosity and moisture status.

In dry soils, gaseous adsorption on the surface of dry colloids introduces a serious error in picnometric determinations. In moist soils gaseous solution in soil moisture while under pressure in the air picnometer and "packing" of water molecules on colloidal surfaces introduce a similar error.

Structure also exerts a marked influence on picnometric determinations either by modifying the area of air-water interface, thus affecting the amount of air dissolved in the soil moisture, or through the effect of structure on the quantity of air which may be trapped and thus not be subject to pressure changes during the determinations.

The air picnometer has various innate weaknesses. It must be checked constantly for leakage. Since changes in atmospheric pressure affect results, calibration curves must be prepared for use at different pressures. The air picnometer must also be recalibrated periodically as variations occur with usage.

Data are presented showing the results of particle-density, soil-porosity, and soil-moisture determinations made by various methods on several soils of Puerto Rico. The relative merits of the various methods are discussed.

RESUMEN

El picnómetro de aire no parece sur un instrumento adaptable para los análisis precisos de densidad de partícula, porosidad, o contenido de humedad del suelo. Sin embargo, parece ser adaptable a aproximaciones de campo en los análisis de porosidad y humedad de suelos.

En suelos secos, la absorción de gases por la superficie expuesta de los coloides, introduce errores apreciables en los análisis con este instrumento. Errores similares ocurren cuando se trata de suelos húmedos. En estos casos los errores se deben a la disolución de gases en la solución del suelo por efecto de la presión ejercida en el instrumento y a la orientación de moléculas de agua en la superficie de los coloides.

La estructura del suelo también ejerce su efecto en la precisión de los análisis, ya sea modificando el área de contacto entre el aire y el agua, variando así la cantidad de aire disuelto en la solución del suelo, o alterando la cantidad de aire aprisionada en los intersticios estructurales del suelo, que por tal razón no son sometidos a los cambios de presión que ocurren durante el análisis.

El picnómetro de aire adolece de varios defectos. Debe ser inspeccionado

constantemente para corregir escapes de aire. Los resultados con este instrumento son afectados por cambios en la presión atmosférica, por lo que se hace indispensable preparar curvas de calibración para adaptarse a las distintas presiones. Este instrumento debe ser recalibrado periódicamente para corregir fluctuaciones resultantes del desgaste por el uso.

Se presentan datos mostrando el resultado de análisis de densidad de partícula, porosidad, y humedad, con diferentes suelos de Puerto Rico, usando varios métodos. Se discuten los méritos relativos a cada uno.

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Termites of the West Indies, the Bahamas, and Bermuda

Thomas E. Snyder[1]

INTRODUCTION

Based on specimens in the collection of the U. S. National Museum, and on authoritative records in literature, the following lists have been compiled of the species of termites known to be present in Bermuda, the Bahamas, the Greater Antilles and the Lesser Antilles of the West Indies, Curacao, and Trinidad. The first list is a systematic arrangement of termites by species; the second list is by islands, giving all the records from each locality. Identifications based on nymphs being very difficult, and for some forms impossible, the concluding keys to the species from these islands are based on the soldiers and winged adults.

TERMITES OF BERMUDA, THE BAHAMAS, AND THE WEST INDIES

Listed by Species

KALOTERMITIDAE

Kalotermes approximatus Snyder: Bermuda.

K. bequaerti Snyder: Bermuda, Cuba, St. Croix, St. Thomas.

K. cubanus Snyder: Cuba.

K. incisus Silvestri: Barbados, Mona Island, St. Croix.

K. jouteli Banks: Bahamas (Andros Island), Cuba.

K. milleri Emerson: Jamaica.

K. mona Banks: Mona Island.

K. schwarzi Banks: Cuba, Jamaica, New Providence (Nassau).

K. snyderi Light: Bermuda, Bimini—Bahamas, Cuba, Mona Island, Puerto Rico, St. Croix.

Neotermes castaneus (Burmeister): Barbados, Cuba, Dominica, Haiti, Jamaica, Montserrat, Puerto Rico, Trinidad.

Neotermes n. sp.: Jamaica.

N. holmgreni Banks: Tobago, Trinidad.

Procryptotermes corniceps (Snyder): Puerto Rico, Mona Island.

Procryptotermes n. sp.: Jamaica.

Cryptotermes brevis (Walker): Barbados, Cuba, Curacao, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Puerto Rico, St. Croix, St. Kitts, St. Lucia, St. Thomas, Tobago, Trinidad.

[1] Retired. Formerly with the Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, USDA, Washington, D. C.

C. cavifrons Banks: Bermuda, Cuba, Haiti, New Providence (Nassau), Puerto Rico, St. Croix.

C. dudleyi Banks: Trinidad.

C. havilandi (Sjostedt): Barbados.

Glyptotermes liberatus (Snyder): Jamaica.

G. posticus (Hagen): Cuba, Jamaica, St. Thomas.

G. pubescens Snyder: Puerto Rico.

Calcaritermes nigriceps (Emerson): Trinidad.

RHINOTERMITIDAE

Heterotermes cardini (Snyder): Bahamas (Andros Island) Nassau, Cuba, Dominican Republic, Haiti.

H. convexinotatus (Snyder): Barbados, Cuba, Haiti, Jamaica, Puerto Rico, St. Croix, St. Thomas.

H. tenuis (Hagen): Bahamas, Cuba, Dominica, Guadeloupe, Haiti, Jamaica, Montserrat, Puerto Rico, Tobago, Trinidad.

Coptotermes havilandi Holmgren: Barbados (introduced), Jamaica (introduced).

C. testaceus (Linnaeus): Tobago, Trinidad.

Prorhinotermes simplex (Hagen): Cuba, Jamaica, Puerto Rico.

Rhinotermes marginalis (Linnaeus): Dominican Republic, Haiti, Martinique.

Dolichorhinotermes longilabius (Emerson): Trinidad.

TERMITIDAE

Anoplotermes banksi Emerson: Trinidad.

A. brevipilis Emerson: Trinidad.

A. meridianus Emerson: Dominican Republic, Haiti, Martinique, Puerto Rico.

A. schwarzi Banks: Cuba.

A. spp.: Haiti, Puerto Rico, Trinidad.

Speculitermes silvestrii (Emerson): Trinidad.

Microcerotermes arboreus Emerson: Haiti, Puerto Rico, Tobago, Trinidad.

M. exiguus (Hagen): Trinidad.

Crepititermes verruculosus (Emerson): Trinidad.

Termes hispaniolae (Banks): Cuba, Haiti, Isle of Pines, Jamaica, Tobago, Trinidad.

T. panamaensis (Snyder): St. Croix, Trinidad.

Cavitermes tuberosus (Emerson): Trinidad.

Neocapritermes angusticeps (Emerson): Trinidad.

Nasutitermes costalis (Holmgren): Antigua, Barbados, Cuba, Dominica,

Dominican Republic, Grenada, Guadeloupe, St. Lucia, St. Kitts, Tobago, Trinidad, Haiti, Jamaica, Martinique, Puerto Rico, St. Croix.

N. ephratae (Holmgren): Guadeloupe, Montserrat, Tobago, Trinidad.

N. guayanae (Holmgren): Trinidad.

N. hubbardi Banks: Cuba, Jamaica.

N. intermedius (Banks): Trinidad.

N. lividus (Burmeister): Cuba, Dominican Republic, Haiti.

N. nigriceps (Haldeman): Curacao, Jamaica, Puerto Rico, St. Croix, St. Thomas, San Salvador, Trinidad, Vieques Island (near Puerto Rico).

N. rippertii (Rambur): Bahamas (Andros Island, Bimini, New Providence, Nassau; Dry Key, and Mangrove Key), Cuba, Eleuthera, Jamaica.

Parvitermes brooksi (Snyder): Biminis, Bahamas; Cuba.

P. discolor (Banks): Cuba, Culebra Island, Puerto Rico.

P. flaveolus (Banks): Haiti.

P. pallidiceps (Banks): Haiti.

P. wolcotti (Snyder): Puerto Rico.

Obtusitermes aequalis (Snyder): Cuba.

Velocitermes antillarum (Holmgren): Dominican Republic, Haiti.

V. toussainti (Banks): Dominican Republic, Haiti.

Labiotermes labralis, subsp. *boreus* (Emerson): Trinidad.

Armitermes holmgreni Snyder: Trinidad.

Angularitermes nasutissimus (Emerson): Trinidad.

Subulitermes baileyi (Emerson): Trinidad.

S. parvellus (Silvestri): Trinidad.

S. snyderi (Emerson): Trinidad.

S. spp.: Trinidad.

Listed by Localities

Bermuda

KALOTERMITIDAE.—*Kalotermes approximatus* Snyder, *K. bequaerti* Snyder, *K. snyderi* Light, *Cryptotermes cavifrons* Banks.

Bahamas, Andros

KALOTERMITIDAE.—*Kalotermes jouteli* Banks.

RHINOTERMITIDAE.—*Heterotermes cardini* (Snyder), *H. tenuis* (Hagen).

TERMITIDAE.—*Nasutitermes rippertii* (Rambur).

Bimini

KALOTERMITIDAE.—*Kalotermes snyderi* Light.

TERMITIDAE.—*Nasutitermes rippertii* (Rambur), *Parvitermes brooksi* (Snyder).

Dry Key, Eleuthera, Mangrove Key

TERMITIDAE.—*Nasutitermes rippertii* (Rambur).

New Providence (Nassau)

KALOTERMITIDAE.—*Kalotermes schwarzi* Banks, *Cryptotermes cavifrons* Banks.

RHINOTERMITIDAE.—*Heterotermes cardini* (Snyder), *H. tenuis* (Hagen).

TERMITIDAE.—*Nasutitermes rippertii* (Rambur).

Antigua

TERMITIDAE.—*Nasutitermes costalis* (Holmgren).

Barbados

KALOTERMITIDAE.—*Kalotermes incisus* Silvestri, *Neotermes castaneus* (Burmeister), *Cryptotermes brevis* (Walker), *C. havilandi* (Sjostedt).

RHINOTERMITIDAE.—*Heterotermes convexinotatus* (Snyder), *Coptotermes havilandi* Holmgren.

TERMITIDAE.—*Nasutitermes costalis* (Holmgren).

Cuba

KALOTERMITIDAE.—*Kalotermes bequaerti* Snyder, *K. cubanus* Snyder, *K. jouteli* Banks, *K. schwarzi* Banks, *K. snyderi* Light, *Neotermes castaneus* (Burmeister), *Cryptotermes brevis* (Walker), *C. cavifrons* Banks, *Glyptotermes posticus* (Hagen).

RHINOTERMITIDAE.—*Heterotermes cardini* (Snyder), *H. convexinotatus* (Snyder), *H. tenius* (Hagen), *Prorhinotermes simplex* (Hagen).

TERMITIDAE.—*Anoplotermes schwarzi* Banks, *Termes hispaniolae* Banks, *Nasutitermes costalis* (Holmgren), *N. hubbardi* Banks, *N. lividus* (Burmeister), *N. rippertii* (Rambur), *Parvitermes brooksi* (Snyder), *P. discolor* (Banks), *Obtusitermes aequalis* (Snyder).

Culebra

TERMITIDAE.—*Parvitermes discolor* (Banks).

Curacao

KALOTERMITIDAE.—*Cryptotermes brevis* (Walker).

TERMITIDAE.—*Nasutitermes nigriceps* (Haldeman).

Dominica

KALOTERMITIDAE.—*Neotermes castaneus* (Burmeister), *Cryptotermes brevis* (Walker).

RHINOTERMITIDAE.—*Heterotermes tenuis* (Hagen).

TERMITIDAE.—*Nasutitermes costalis* (Holmgren).

Dominican Republic

KALOTERMITIDAE.—*Cryptotermes brevis* (Walker).

RHINOTERMITIDAE.—*Heterotermes cardini* (Snyder), *Rhinotermes marginalis* (Linnaeus).

TERMITIDAE.—*Anoplotermes meridianus* Emerson, *Nasutitermes costalis* (Holmgren), *N. lividus* (Burmeister), *Velocitermes antillarum* (Holmgren), *V. toussainti* (Banks).

Grenada

KALOTERMITIDAE.—*Gryptotermes brevis* (Walker).

TERMITIDAE.—*Nasutitermes costalis* (Holmgren).

Guadeloupe

KALOTERMITIDAE.—*Cryptotermes brevis* (Walker).

RHINOTERMITIDAE.—*Heterotermes tenuis* (Hagen).

TERMITIDAE.—*Nasutitermes costalis* (Holmgren), *Nasutitermes ephratae* (Holmgren).

Haiti

KALOTERMITIDAE.—*Neotermes castaneus* (Burmeister), *Cryptotermes brevis* (Walker), *C. cavifrons* Banks, *Glyptotermes posticus* (Hagen).

RHINOTERMITIDAE.—*Heterotermes cardini* (Snyder), *H. convexinotatus* (Snyder), *H. tenuis* (Hagen), *Rhinotermes marginalis* (Linnaeus).

TERMITIDAE.—*Anoplotermes meridianus* Emerson, *Anoplotermes* spp., *Microcerotermes arboreus* Emerson, *Termes hispaniolae* (Banks), *Nasutitermes costalis* (Holmgren), *N. lividus* (Burmeister), *Parvitermes flaveolus* (Banks), *P. pallidiceps* (Banks), *Velocitermes antillarum* (Holmgren), *V. toussainti* (Banks).

Isle of Pines

TERMITIDAE.—*Termes hispaniolae* (Banks).

Jamaica

KALOTERMITIDAE.—*Kalotermes milleri* Emerson, *K. schwarzi* Banks, *Neotermes castaneus* (Burmeister), *Neotermes* n. sp., *Procryptotermes* n. sp., *Cryptotermes brevis* (Walker), *Glyptotermes liberatus* (Snyder), *G. posticus* (Hagen).

RHINOTERMITIDAE.—*Heterotermes convexinotatus* (Snyder), *H. tenuis* (Hagen), *Coptotermes havilandi* Holmgren, *Prorhinotermes simplex* (Hagen).

TERMITIDAE.—*Termes hispaniolae* (Banks), *Nasutitermes costalis* (Holmgren), *N. hubbardi* Banks, *N. nigriceps* (Haldeman).

Martinque

RHINOTERMITIDAE.—*Rhinotermes marginalis* (Linnaeus).

TERMITIDAE.—*Anoplotermes meridianus* Emerson, *Nasutitermes costalis* (Holmgren).

Mona

KALOTERMITIDAE.—*Kalotermes incisus* Silvestri, *K. mona* Banks, *K. snyderi* Light, *Procryptotermes corniceps* (Snyder).

Montserrat

KALOTERMITIDAE.—*Neotermes castaneus* (Burmeister).

RHINOTERMITIDAE.—*Heterotermes tenuis* (Hagen).

TERMITIDAE.—*Nasutitermes ephratae* (Holmgren).

Puerto Rico

KALOTERMITIDAE.—*Kalotermes snyderi* Light, *Neotermes castaneus* (Burmeister), *Procryptotermes corniceps* (Snyder), *Cryptotermes brevis* (Walker), *C. cavifrons* Banks, *Glyptotermes pubescens* Snyder.

RHINOTERMITIDAE.—*Heterotermes convexinotatus* (Snyder), *H. tenuis* (Hagen), *Prorhinotermes simplex* (Hagen).

TERMITIDAE.—*Anoplotermes meridianus* Emerson, *Microcerotermes arboreus* Emerson, *Nasutitermes costalis* (Holmgren), *N. nigriceps* (Haldeman), *Parvitermes discolor* (Banks), *P. wolcotti* (Snyder).

St. Kitts (St. Christopher)

KALOTERMITIDAE.—*Cryptotermes brevis* (Walker).

TERMITIDAE.—*Nasutitermes costalis* (Holmgren).

St. Lucia

KALOTERMITIDAE.—*Cryptotermes brevis* (Walker).

TERMITIDAE.—*Nasutitermes costalis* (Holmgren).

San Salvador (Watling)

TERMITIDAE.—*Nasutitermes nigriceps* (Haldeman).

Tobago

KALOTERMITIDAE.—*Neotermes holmgreni* Banks, *Cryptotermes brevis* (Walker).

RHINOTERMITIDAE.—*Heterotermes tenuis* (Hagen), *Coptotermes testaceus* (Linnaeus).

TERMITIDAE.—*Microcerotermes abroreus* Emerson, *Termes hispaniolae* (Banks), *Nasutitermes costalis* (Holmgren), *N. ephratae* (Holmgren).

Trinidad

KALOTERMITIDAE.—*Neotermes castaneus* (Burmeister), *N. holmgreni* Banks, *Cryptotermes brevis* (Walker), *C. dudleyi* Banks, *Calcaritermes nigriceps* (Emerson).

RHINOTERMITIDAE.—*Heterotermes tenuis* (Hagen), *Coptotermes testaceus* Linnaeus), *Dolichorhinotermes longilabius* (Emerson).

TERMITIDAE.—*Anoplotermes banksi* Emerson, *A. brevipilis* Emerson, *Anoplotermes* spp., *Speculitermes silvestrii* (Emerson), *Microcerotermes arboreus* Emerson, *M. exiguus* (Hagen), *Crepititermes verruculosus* Emerson, *Termes hispaniolae* (Banks), *T. panamaensis* (Snyder), *Cavitermes tuberosus* Emerson), *Neocapritermes angusticeps* (Emerson), *Nasutitermes costalis* Holmgren), *N. ephratae* (Holmgren), *N. guayanae* (Holmgren), *N. intermedius* Banks, *N. nigriceps* (Haldeman), *Labiotermes labralis*, subsp. *boreus* Emerson), *Armitermes holmgreni* Snyder, *Angularitermes nasutissimus* Emerson), *Subulitermes baileyi* (Emerson), *S. parvellus* (Silvestri), *S. snyderi* (Emerson), *Subulitermes* spp.

Virgin Islands, St. Croix

KALOTERMITIDAE.—*Kalotermes bequaerti* Snyder, *K. incisus* Silvestri, *K. snyderi* Light, *Cryptotermes brevis* (Walker), *C. cavifrons* Banks.

RHINOTERMITIDAE.—*Heterotermes convexinotatus* (Snyder).

TERMITIDAE.—*Termes panamaensis* (Snyder), *Nasutitermes costalis* Holmgren), *N. ephratae* (Holmgren), *N. nigriceps* (Haldeman).

Virgin Islands, St. Thomas

KALOTERMITIDAE.—*Kalotermes bequaerti* Snyder, *Cryptotermes brevis* Walker), *Glyptotermes posticus* (Hagen).

RHINOTERMITIDAE.—*Heterotermes convexinotatus* (Snyder).

TERMITIDAE.—*Nasutitermes nigriceps* (Haldeman).

Virgin Islands, Vieques

TERMITIDAE.—*Nasutitermes nigriceps* (Haldeman).

Key to the Termites of the West Indies

BASED ON SOLDIERS

Soldier absent, body worker fusiform, post clypeus strongly arched, pronotum saddle shaped, tibiae forelegs swollen.....*Anoplotermes schwarzi* Banks

Soldier present.....1

1. Mandibles degenerated into small functionless structures, with or without points, long projection in front of head.....2
   Mandibles not degenerated.....18

2. Projection in front of head (labrum) long and narrow, forked at tip (minor-soldier)
   Labrum wider than long (major-soldier)
   Rhinotermes marginalis (Linneaus)
   Labrum longer than broad (major-soldier)
   Dolichorhinotermes longilabius (Emerson)
   Projection in front of head not forked at tip, but prolonged into a nasus....3
3. Head usually with conspicuous constriction in middle, base mandibles with points....4
   Head of soldier with slight constriction in middle, base mandibles without points....9
   Head of soldier without constriction in middle, base mandibles with points....12
4. Third segment of antenna plainly longer than second....5
   Third segment of antenna not longer than second....7
5. Head plainly constricted....6
6. Head and antennae dark brown...*Velocitermes antillarum* (Holmgren)
   Head yellow-brown....*Parvitermes wolcotti* (Snyder)
   Head but slightly constricted, yellow-brown, finely haired
   Parvitermes discolor (Banks)
7. Head plainly constricted....8
   Head but slightly constricted....*Parvitermes brooksi* (Snyder)
8. Head and antennae brown, femora brownish
   Velocitermes toussainti (Banks)
   Head, antennae and legs pale yellowish..*Parvitermes flaveolus* (Banks)
9. Nasus short and conical....10
   Nasus long and slender....11
10. Head yellow brown, second and third segments antennae of equal length....*Obtusitermes aequalis* (Snyder)
    Head pale yellow, third segment antenna longer than second
    Parvitermes pallidiceps (Banks)
11. Head convex, antennae with 11 segments
    Subulitermes parvellus (Silvestri)
    Head slightly indented in middle, antennae with 12 segments
    Sublitermes snyderi (Emerson)
12. Head covered with hairs....13
    Head covered with few hairs....15
13. Head pale yellowish....*Nasutitermes rippertii* (Rambur)
    Head brownish....14
14. Head reddish or blackish-brown....*Nasutitermes nigriceps* (Haldeman)

15. Head with 10 or more hairs, nasus short
Nasutitermes guayanae (Holmgren)
Head with 10 hairs, nasus long ..... *Nastuitermes intermedius* Banks
Head with 6 or less hairs, one each side near vertex 16
16. Four distinct hairs above base of nasus, nasus much shorter than head 17
Hairs above base nasus very small, nasus nearly as long as pale head
Nasutitermes hubbardi Banks
17. Head reddish-brown, nasus short, smaller
Short hairs on abdominal tergites, nasus thicker and more conical
Nasutitermes costalis (Holmgren)
Short hairs absent ..... *Nasutitermes ephratae* (Holmgren)
18. Head longer than broad, castaneous 19
Head short, front cavate mandibles without marginal teeth prominent 34
19. Mandibles with prominent marginal teeth 20
Mandibles without prominent marginal teeth 28
Mandibles with minute serrations
Length head 2.67–2.73 mm ..... *Microcerotermes arboreus* Emerson
Length head shorter ..... *Microcerotermes exiguus* (Hagen)
20. Head with nasus ..... *Armitermes holmgreni Snyder*
Head without nasus but with tube projecting from frontal gland
Labiotermes labralis, subsp. *boreus* (Emerson)
Head without nasus or tubes 21
21. Forehead deeply lobed or steeply sloping 22
Forehead not deeply lobed or steeply sloping 23
22. Front almost vertical, lobed
Head short, gula slender at middle
Glyptotermes pubescens (Snyder)
Head elongate, gula very slender at middle
Glyptotermes liberatus (Snyder)
Front steeply sloping, not lobed, knob on each side front head
Procryptotermes corniceps (Snyder)
23. Hind femora slender, third segment antenna not modified
Neotermes castaneus (Burm.)
Hind femora swollen, third segment antenna modified 24
24. Third segment antenna scarcely, if at all, longer than second 25
Third segment antenna plainly longer than second 26
25. Eyespot black, mandibles not very broad ..... *Kalotermes mona* Banks
Eyespot black, mandibles very broad ..... *Kalotermes cubanus* Snyder
Eyespot hyaline ..... *Kalotermes schwarzi* Banks

26. Eyespot black, gula very broad.....*Kalotermes jouteli* Banks
Eyespot hyaline, gula slender, anterior margin of pronotum finely serrate.....27
27. Length 7–8 mm.....*Kalotermes synderi* Light
Length 5–7 mm.....*Kalotermes bequaerti* Snyder
28. Head with large tube in front.....*Coptotermes testaceus* (Linn.)
Head without tube.....29
29. Mandibles long, slender, somewhat asymmetrical.....30
Mandibles shorter, stouter at base, more symmetrical.....32
30. Head cavate in middle.....*Cavitermes tuberosus* (Emerson)
Head not cavate in middle.....31
31. Third segment antenna shorter than second
Termes panamaensis (Snyder)
Third segment antenna longer than second
Termes hispaniolae (Banks)
32. Labrum rounded at tip, head broader behind, fontanelle distinct
Prorhinotermes simplex (Hagen)
Labrum pointed at tip, head hardly broader behind, fontanelle indistinct.....33
33. Head with many hairs.....*Heterotermes tenuis* (Hagen)
Head with few hairs.....*Heterotermes cardini* (Snyder)
Head with very few hairs.....*Heterotermes convexinotus* (Snyder)
34. Head blackish, anterior tuberculate.....*Cryptotermes brevis* (Walker)
Head blackish, anterior not tuberculate, head 1.5 mm. long, pronotum anteriorly deeply emarginate.....*Cryptotermes cavifrons* Banks
Head longer 1.72 mm., pronotum anteriorly slightly emarginate
Cryptotermes havilandi (Sjostedt)

BASED ON WINGED ADULTS

1. Fontanelle or head gland absent, forewing scale usually not much longer than pronotum, branches between costal and subcostal veins.....2
Fontanelle usually present, forewing scale longer than flat pronotum, no branches between costal veins.....8
Fontanelle usually present with plate, forewing scale shorter than saddle-shaped pronotum, no branches between costal veins.....13
2. Median vein heavy, close to costal vein.....3
Median vein light, free from costal veins.....6
Median vein light, usually united with subcostal vein near middle of wing.....7
3. Wing membrane stippled, small species.....4
Wing membrane clear, large species.....5

4. Head dark castaneous brown, third segment antenna shorter than second ..... *Glyptotermes pubescens* (Snyder)
Head and thorax red-brown ..... *Glyptotermes liberatus* Snyder
Head yellow-brown, third segment antenna longer than second
Procryptotermes corniceps (Snyder)
5. Length 21 mm., eye large ..... *Kalotermes mona* Banks
Length 18 mm., eye smaller ..... *Neotermes castaneus* (Burm.)
6. Head and thorax yellow to castaneous, 10–16 mm. in length
Short hairs on tergites, head yellowish, length 12 mm.
Kalotermes jouteli Banks
Long erect hairs on tergites
Ocelli oblique, head yellowish, length 15–16 mm.
Kalotermes schwarzi Banks
Ocelli oblique, head castaneous, length 10 mm., pulvillus between tarsal claws prominent ..... *Kalotermes bequaerti* Snyder
Ocelli round, length 11–12 mm., pulvillus absent
Kalotermes snyderi Light
7. Length 10 mm. ..... *Cryptotermes brevis* (Walker)
Length 8.5 mm. ..... *Cryptotermes cavifrons* Banks
Length 8 mm. ..... *Cryptotermes havilandi* (Sjostedt)
8. Median vein absent, wing margin not ciliate, fontanelle very distinct, yellowish-brown, length 9 mm. ..... *Prorhinotermes simplex* (Hagen)
Median vein present 9
9. Wing membrane punctate, wing margins ciliate, ocelli present or absent, fontanelle indistinct or absent, in middle of head 10
Wing membrane reticulate, ocelli present, fontanelle in front or middle head 12
10. Wing surface with many hairs, posterior margin of meso- and metanota emarginate and not covered by wing scale
Heterotermes tenuis (Hagen)
Wing surface with few hairs, posterior margin of meso- and metanota convex and covered by wing scale 11
11. Cubitus vein and branches spread over more than one-half of width of wing, median near cubitus ..... *Heterotermes cardini* (Snyder)
Cubitus and branches spread over less than half of width of wing, median intermediate ..... *Heterotermes convexinotatus* (Snyder)
12. Head with small nasus-like process over clypeus, fontanelle near front head, 3d. joint antenna longer than 1st
Rhinotermes marginalis (Linnaeus)
3d. joint antenna shorter than 1st
Dolichorhinotermes longilabius (Emerson)

Head without process, fontanelle in middle head
Coptotermes testaceus (Linneaus)

13. Fore tibiae with two spines....14
Fore tibiae with three spines....20

14. Left mandible with two nearly equal apical teeth, post-clypeus much shorter than half its width; pronotum weakly saddle-shaped, cubital vein ends much before tip of wing....15
Left mandible with first tooth longer than second, post-clypeus about as long as half its width or if shorter strongly arched, fontanelle slender, elongate....17
Left mandible with equal apical teeth, post-clypeus as long as half its width or if shorter, arched....19

15. Fontanelle white, conspicuous, triangular, large eyes and ocelli, ocelli close to eyes, antennae 17-segmented, first branches cubitus heavier than others....*Labiotermes labralis*, subsp. *boreus* (Emerson)
Fontanelle small, round, inconspicuous, eyes and ocelli medium sized, ocelli more distant from eyes, antennae 15-segmented; first branches cubitus heavier than others....*Armitermes holmgreni* Snyder
Fontanelle elongate, triangular, antennae 15-segmented,
Wings and thorax blackish, eyes small not projecting, ocelli more than diameter from eye....*Nasutitermes costalis* (Holmgren)
Wings and thorax more yellowish
Eyes medium-sized, medium-close to margin head, ocelli close to eyes
Pronotum rounded on sides; much narrowed behind
Nasutitermes ephratae (Holmgren)
Pronotum not so much narrowed behind, ocelli larger, nearer to eyes....*Nasutitermes lividus* (Burm.)
Eyes very large, projecting, close to margin head, ocelli large, close to eyes, fontanelle elongate, slit-shaped
Pronotum obliquely narrowed on sides....16

16. Pronotum somewhat emarginate posteriorly
Length 17–18 mm....*Nasutitermes nigriceps* (Hald.)
Length 16–17 mm....*Nasutitermes rippertii* (Rbr.)
Length 13–15 mm....*Nasutitermes intermedius* Banks
Pronotum markedly marginate posteriorly, fontanelle not so elongate, antennae 16-segmented....*Nasutitermes guayanae* (Holmg.)

17. Third segment antenna not longer than second, mandibles short and broad....18
Third segment antenna very short, mandibles long, fontanelle a raised spot, meso- and meta-nota notched, head densely hairy, 2 mm. broad....*Anoplotermes schwarzi* Banks

Head less densely hairy, less broad
Anoplotermes meridianus Emerson

18. Eye large, prominent, second segment antenna longer than third, antenna with 14 segments..... *Subulitermes snyderi* (Emerson)
Eye fairly large, not prominent, second segment antenna equal to third, antenna with 16 segments..... *Subulitermes parvellus* (Silvestri)

19. Third segment antenna plainly longer than second, mandibles short and broad, eye small, projecting, head arched behind
Antennae with 12–13 segments, head brownish..... *Parvitermes* spp.
Antennae with 16 segments, head darker
Velocitermes antillarum (Holmgren)

20. Mandibles with very large first tooth, post-clypeus large, arched, about as long as half its breadth, fontanelle, eyes and ocelli small, pronotum flat, cubital vein ends near tip of wing.....21
Mandibles with subequal apical teeth, head oval, parallel sided; pronotum saddle-shaped, eyes and ocelli small, fontanelle indistinct.....23

21. Fontanelle round..... *Cavitermes tuberosus* (Emerson)
Fontanelle slit-shaped.....22

22. Length 8 mm., wing scale as long as pronotum
Termes hispaniolae (Banks)
Length shorter, wing scale shorter than pronotum
Termes panamaensis (Synder)

23. Length 9 mm.,..... *Microcerotermes arboreus* Emerson
Length shorter..... *Microcerotermes exiguus* (Hagen)

SUMMARY

Many of the termites of the West Indies are endemic, and so far as known, have a very limited distribution, often recorded from only a few islands. *Kalotermes mona* Banks is endemic to Mona Island and is found nowhere else. By contrast, many of the termites occuring in Cuba are also found in the United States, those of Jamaica in Panamá and Central America, and those of Trinidad in South America. The truly tropicosmopolitan *Cryptotermes brevis* (Walker) and *Nasutitermes costalis* (Holmgren) readily become established in new localities, islands or countries in which the environmental conditions are at all suitable.

The comparatively large island of Trinidad, close to the mainland of South America and mostly with a continental fauna, has the largest number of species of termites of any of the West Indies: 31. The island of Curaçao, also near the coast of South America, but small and arid has but 2, and none is recorded from Aruba, Margarita or the other smaller islands off the north coast of Venezuela. The comparatively small island of Tobago, northeast from Trinidad, has 8 species of termites recorded, and Barbados

7, but none is listed from St. Vincent, and most of the other Lesser Antilles have at most but 3 or 4. None is reported from Nevis, Saba, or St. John, but St. Croix of the U. S. Virgin Islands has 10, St. Thomas 5, and Culebra and Vieques 1 each. Fifteen species of termites are recorded from Puerto Rico, and 4 from Mona. In the large island of Hispaniola, only 8 species of termites are recorded from the eastern portion: the Dominican Republic, while 18 are known from Haiti. Sixteen species of termites are known in Jamaica, and 9 from the widely dispersed islands of the Bahamas. The large island of Cuba, closest of any to continental North America, has 22; the comparatively minute, and most distant Bermuda has 4.

All recorded species may be identified by means of keys based on the characters of the soldiers, or of the winged adults.

RESUMEN

Muchos de los comejenes de las Antillas son endémicos. Hasta donde se sabe, tienen una distribución muy limitada por lo que sólo existen récords de su presencia en muy pocas islas. A modo de contraste, muchos de los comejenes de Cuba también se pueden encontrar en los Estados Unidos; los de Jamaica en Panamá y los de Trinidad en Sur América. Los verdaderos cosmopolitas del Trópico, el *Cryptotermes brevis* (Walker) y el *Nasutitermes costalis* (Holmgren) se establecen fácilmente en nuevas localidades, islas o países donde las condiciones del medio ambiente les son favorables.

La comparativamente extensa isla de Trinidad, cerca del continente de Sur América cuya fauna es casi la misma que la continental, tiene el mayor número de comejenes entre todas las Antillas, el cual asciende a 31. La isla de Curazao, también cerca de la costa suramericana, y con un área pequeña y árida sólo tiene 2 especies. Aruba no tiene, tampoco Margarita ni las otras islas más pequeñas cerca de la costa norte de Venezuela. La relativamente pequeña isla de Tobago, al noroeste de Trinidad tiene 8 especies de comején, Barbada tiene 7, pero según la lista St. Vincent no cuenta con especie alguna. La mayoría de las Antillas Menores sólo tiene 3 ó 4. Nevis, Saba y St. John no tienen, pero St. Croix en las Islas Vírgenes Americanas informa tener 10 y St. Thomas 5. Culebras y Vieques informan 1 especie cada una.

Hay en récord 15 especies de comején en Puerto Rico. La Mona tiene 4. La Española, isla de gran extensión territorial, tiene 8 especies en su región oriental ocupada por la República Dominicana, mientras que en Haití hay 18. Los récords señalan que en Jamaica hay 16 especies de comején y 9 especies están dispersas entre las islas Bahamas. La gran isla de Cuba, la más cercana al continente de Norte America tiene 22 especies, la comparativamente diminuta Bermuda tiene 4.

Todos las especies en récord se pueden identificar por medio de claves, las cuales se basan en los caracteres de los soldados, o en los adultos alados.

Research Notes

THE INSECTS OF "ALMENDRON," PRUNUS OCCIDENTALIS SW.[1]

The "Almendrón" of Puerto Rico, Dominican Republic, and Cuba, *Prunus occidentalis* Swartz, is an endemic tree of the mountainous areas of both the Greater and the Lesser Antilles. The smooth-skinned, dark-purplish fruit is shaped like a small prune, which in Puerto Rico matures in mid-June. Although edible, it is hardly to be recommended for human consumption as all collected locally have been heavily infested with the maggots of the fruitfly, *Anastrepha suspensa* Loew. This is the fruitfly which, at lower elevations, attacks the fruit of guava, pomarrosa, the husks of almendro, and overripe grapefruit and oranges. In Martinique, a liquer is prepared from the fruit of the almendrón: the locally celebrated "Noyau."[2]

The economic importance of the almendrón does not depend on its fruit, but on its wood, which although not adapted for use outdoors exposed to the weather, is hard and durable and is more resistant than the heartwood of genuine West Indian mahogany, *Swietenia mahagoni* Jacq., to the attack of the "polilla," *Cryptotermes brevis* Walker.[3] So few are the timbers of Puerto Rico which are more resistant than mahogany to the dry-wood termite, that each one merits especial attention.

The entomologists have been making observations on a nursery of trees discarded by the U. S. Forest Service and now 6 to 9 feet tall, located below the swimming pool of the Doña Juana Recreation Area of the Toro Negro Unit. Almendrón trees are not outstandingly conspicuous, either individually or en masse, and the plain oval leaves vary so considerably in size as not to be distinctive. Rarely one may find on an otherwise uninjured leaf what looks like a spot of undried paint, its surface somewhat interrupted by scattered pustules. Submitted to John A. Stevenson of the Plant Disease Epidemics and Identification Section of USDA at Beltsville, Md., this unique fungus was identified by Wm. W. Diehl as *Rhytisma leptospilum* Berk. *et* Curt. Unfortunately, it is not merely a very interesting mycological specimen, for José Marrero a few months ago found it attacking not only leaves, but twigs and stems of seedlings in a nursery at higher elevations.

A most beautiful vaquita, black-striped with iridescent scales of blue-

[1] Presented at the Autumn Meeting, American Society of Agricultural Sciences, held at Isabela, P. R., Nov. 18, 1955.

[2] Record, Samuel J., and Hess, Robert W., (p. 452), Timbers of the New World, Yale University Press, New Haven, Conn., 1941.

[3] Wolcott, George N., A list of woods arranged according to their resistance to the attach of the West Indian dry-wood termite, *Cryptotermes brevis* Walker, *Caribbean Forester* **7** (4) 329–36, 1946.

green, of which a single female was found ovipositing between coffee leaves at Maricao in 1921, was described in Insectae Portoricensis[4] as *Compsus maricao* Wolcott, and for some years constituted the only individual known. Since observations were started on the nursery of almendrón trees at Doña Juana, dozens of individuals of both sexes have been found, and indeed occur in such abundance that many of the seedlings have been largely defoliated. Bright-yellow individuals of the common vaquita, *Diaprepes abbreviatus* L., are almost equally abundant, especially on the unshaded trees, and the combination of the two species constitutes a serious pest.

Several trees in the nursery are heavily infested with the common white scale of papaya, *Pseudalacaspis pentagona* (Targioni), and no predaceous ladybeetles have appeared spontaneously to check this outbreak.

The tender leaves of almendrón were noted last winter infested with two species of aphid: The green peach aphid, *Myzus persicae* (Sulzer), and in much greater abundance but causing no curling of the leaves, the spiraea aphid, *Aphis spiraecola* Patch.[5] No aphids have been noted during the spring, summer, and autumn, and even in the winter they are so scarce as to be of little economic importance.

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RESISTANCE BY PLANT TISSUE HIGH IN SILICA TO INJURY BY CYANIDE AND MARINE BORERS

Because of comparatively ready availability—proximity to the Manatí-Ciales road—a large "jagüey" tree, *Ficus laevigata* L., heavily infested with "hormiguilla," the coffee shade-tree ant, *Myrmelachista ramulorum* Wheeler, was used for a number of years for conducting experiments in the control of this ant. Before Aldrin became commercially available, and indeed before its value in the control of hormiguilla had even been considered, the most promising method of killing these ants was to use bits of hamburg steak as an attractant, mixed with cyanide of potassium as a toxicant. Enormous numbers of ants were experimently killed using this combination of poison and bait, applied directly to the bark of the jagüey tree, without any indication of injury to the bark or any other part of the tree.

The tests were so successful indeed as to suggest continuation on a large scale in a commercial coffee grove on shade trees of *Inga vera* Willd. and *Inga laurina* (Sw.) Willd. A few weeks after application of the steak-cyanide

[4] "Insectae Portoricensis," a preliminary annotated check-list of the insects of Porto Rico, with descriptions of some new species, *J. Dept. Agr. P. R.*, **7** (1) 5-313, 1923.

[5] Dispersion to the Tropics of the Spiraea aphid, *Aphis spiraecola* Patch, *J. Agr. Univ. P. R.*, **39** (1) 32–40, fig. 1, ref. 14, 1955.

mixture to the bark of these trees, considerable areas around the point of application were showing signs of injury as indicated by the boring exudations from the tunnels of shot-hole borer beetles, *Xyleborus affinis* Eichoff. If the steak-cyanide mixture was applied in a ring completely around the trunk of the tree, so that the ants could not avoid or by-pass it, the entire tree was killed. Clearly, some other arrangement had to be made if this poison bait were to be used on *Inga* trees, and the next development was to use flexible thin sheets of metal on which to place the bait, or containers of flexible metal. The fact that the bark of the jagüey tree had suffered no injury was completely ignored, and was hardly considered important, as it had no bearing on the hormiguilla control project. It is only now, in the light of quite different investigations by another worker, that it assumes significance.

The jagüey of Puerto Rico, *Fiscus laevigata* L., is an endemic tree, but of another species of fig, *Ficus indica* L., the marine biologist, C. H. Edmondson, reporting on "Resistance of Woods to Marine Borers in Hawaiian Waters"[1], on page 43, writes: "Chemical analysis by Yard Testing Laboratory (U. S. Navy, Pearl Harbor, Oahu, T. H.): Wood contains less than 0.01 percent of silica, very light; alkaloids, none. Bark contains 2.30 percent silica; tannins, light; alkaloids, none."

He continues, that all of eight species of seasoned *Ficus* wood exposed six months in Honolulu harbor were

> ... badly damaged by teredos and usually lightly attacked by *Limnoria*. Greater resistance of green sections protected by bark was noted, especially of *F. macrophylla*, *F. retusa*, and *F. rubiginosa*. Seasoned bark of *Ficus indica*, 18 mm. thick, used as test blocks was but lightly attacked by teredos during periods up to two years, with maximum penetration of 10 mm., after which it showed evidence of failure. The resistance of this bark is probably due to its high silica content. Seasoned wood of this species, unprotected by bark, is riddled by teredos in five months.
>
> Numerous investigators have stressed the importance of silica, and attributed the durability of particular woods under maritime conditions to the presence of considerable amounts of this substance in their tissues. D. R. Nanji, and W. S. Shaw, writing of "The Role of Silica in Plant Growth; its Assimilation and Physiological Relation to Phosphoric Acid" (Jour. Soc. Chemical Industry, Trans., **44** (1): 1–6, 1925), "conclude that about 90 percent of the total silica in plants is present as free silicic acid, probably in a colloidal state, whereas the other 10 percent is probably in combination with a polysaccharide constituent of the plant, in a form only to be extracted after treatment with acid. It is well known that silica may occur in the cells and fibers of plants in the form of granular inclusions which can be detected under proper technique.

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[1] Bishop, Bernice P., Museum Bulletin 217, pp. 91, fig. 27, ref. 38. 1955, Honolulu, T.H.

PRELIMINARY NOTE ON THE SOCALLED RECOVERY OF THE CANE VARIETY B. 34104 FROM THE SUGARCANE MOSAIC VIRUS IN PUERTO RICO

According to Martyn, reporting from Jamaica[1], sugarcane varieties B. 34104 and B. 37161 are unaffected by the sugarcane-mosaic virus found there. He further states, still referring to B. 34104, that "unfortunately the leaf symptoms, often not very distinct on this variety, vanish almost entirely as the cane matures."

Because of their excellent agronomic qualities these two canes, especially B. 34104, have been increasing in popularity with the growers of the Island. Many of our farmers believe that the sugarcane variety B. 34104, although susceptible to mosaic, can produce more sugar than the currently known commercial varieties and, what is more, that this variety recovers from the disease.

The first claim has been amply refuted now by the experiments of González and Adsuar[2] which clearly demonstrated a reduction of 30 percent in tonnage of cane and of 34 percent in the total sugar produced when diseased was compared with healthy cane.

The following experiment was performed to clarify the second claim, that is, that B. 34104 and B. 37161 recover from mosaic. Single three-eyed cuttings taken from healthy stools of both varieties were planted in 6-inch pots. When the plants were about 10 inches high they were inoculated on the leaves by rubbing with carborundum, using as inoculum juice extracted from variety B. 10-12 infected with moasic. Sorghum (*Holcus sorghum* L.) seedlings[3] were inoculated as checks to test the infectiousness of the juice. When symptoms developed on the inoculated canes they were taken to the field and planted in two rows 6 feet apart, 21 plants per row, the plants also being 6 feet apart in the row.

About 6 months later the field was inspected and it was found that five plants of B. 34104 and three plants of B. 37161 had apparently recovered from the disease. To test the possibility that, although not showing symptoms, the recovered canes might carry the virus in a latent or masked form, juice was extracted from leaves of each recovered cane and inoculated on sorghum seedlings. The inoculations were repeated at least twice. None of the sorghum seedlings inoculated with juices extracted from the different recovered B. 34104 and B. 37161 canes showed symptoms of mosaic. It was concluded that the plants had recovered fully and that the virus was

[1] Martyn, E. B., Sugar cane mosaic in Jamaica, *Trop. Agr.* **23** (7) July 1946.

[2] González Ríos, P., and Adsuar, J., Effect of mosaic on the yield of sugarcane variety B. 34-104, *J. Agr. Univ. P. R.* **37** (1) 13-8, 1953.

[3] Adsuar, J., On the physical properties of sugarcane mosaic virus, *Phytopath.* **40** (2) 214-6, 1950.

absent from their tissues insofar as biological means of detection, using a highly susceptible host, was concerned.

However, it was considered of interest also to determine whether the recovered canes were still susceptible to reinfection. Cuttings taken from the recovered canes of both varieties were brought to the greenhouse, planted, and inoculated as described above with infective juice from the same source as was used in the previous inoculations. All the plants grown from cuttings from recovered canes show symptoms of mosaic when inoculated with sugarcane mosaic virus.

As a result of these preliminary experiments it is concluded that varieties B. 34104 and B. 37161, may recover to some degree from mosaic, but[2] the recovered canes are still susceptible to reinfection by the sugarcane-mosaic virus.

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(Continued from inside front cover)

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[3] Leave to pursue studies.
[4] Military leave.